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Photography of Metals

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Photography is rightly regarded as an indispensable tool in industry and research, and although in other respects it enters into the life of almost everyone, its application to the investigation of metals is the more direct concern of the author of this article. The subject is discussed in three main sections; straight camera photography; photomicrography; low-power photomicrography, and macrophotography.

THE diversity and importance of the applications of photography are generally appreciated, but it is the application of photography by the scientific worker, especially the metallurgist, with which this article is concerned. The photography of metals is considered under three main sections: straight photography; photomicrography; and low-power photomicrography and macrophotography. The first of these is discussed in this part of the article under three further headings—viz., apparatus, preparation of subject, and photography.

Straight Camera Photography

The straight photography of metals does not call for a great amount of equipment, but rather a technique for dealing with the high reflectivity of the metal surfaces involved.

The problem is not usually one of reproducing the particular feature required, but of producing a picture as well. The great handicap in this work is the impracticability of reproducing all the results stereoscopically.

The work may well be divided into two types: pictorial and technical. The former is that which requires to be a picture as well as showing some special feature, while the latter applies to that which requires to show only the results of some particular test.

Apparatus.—In the case of pictorial photography a half-plate Sanderson camera is usually required, with a stout portable tripod which can be used either in the studio or out of it. A useful range of lenses is from 3 in. focal length wide angle up to about 12 in. focal length, all being anastigmats. Two 500-watt Focuslite spotlights are a necessary source of illumination as well as any other type of studio lighting that may be available. Cambric head-screens, tissue paper and white paper are all useful for screening off unnecessary light as well as for softening down hard shadows.

Most technical photography can be accomplished with the apparatus used for pictorial work, but a half-plate copying camera and stand are extremely useful. As copying stands are not readily obtainable, the following description and Fig. 1 should enable anyone doing this kind of work to have one made up. This stand consists essentially of four legs and a back. Sliding on the back is a bench top 7 in. wide, which carries the easel and camera. The camera is carried on a box which in turn slides on the bench, the box being of sufficient height for full use to be made of the camera movements. The easel is made in two parts, and the front portion is hinged vertically to the back portion so that it can be swung out should it be desirable to obtain a different view-point. It can also be swung round so as to form an extended easel with the back portion. Attached to this front portion is a shelf which can be raised or lowered to any required position and is strong enough to take fairly heavy specimens.

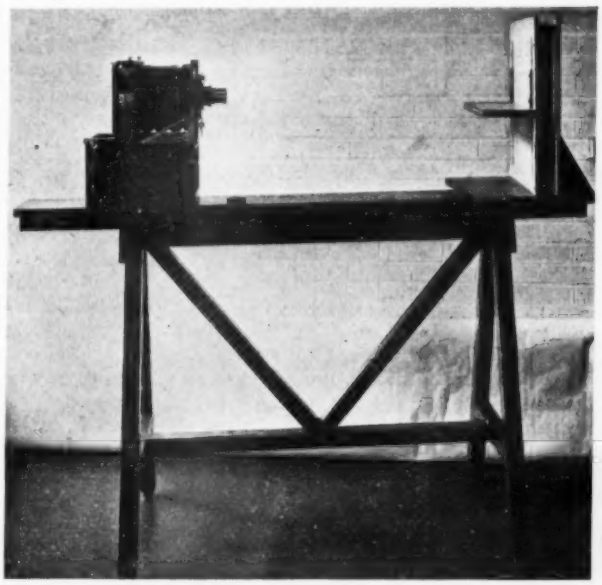


Fig. 1.—Camera stand

There is another small piece of apparatus which is extremely useful. Since both the cameras mentioned above have double book-form dark slides, it is possible to fit them with normal quarter-plate adaptors. Two very useful adaptors are obtained by making the recesses for the quarter-plate at one end of the adaptors, the first having the long side of the quarter-plate in the short side of the half-plate, and the second having the short side of the quarter-plate in the short side of the half-plate. A pair of each of these types of adaptors are useful for stereoscopic photography by the lens displacement method. Other methods are described below.

Preparation of Subject.—It is not intended to discuss composition and set up of the pictorial work, but rather to mention one or two difficulties and the method of overcoming them.

Highly reflective articles, such as bright tinned ware, usually give the most trouble. Not only are the reflections numerous, but the irregular shapes cause the objects to reflect from different directions. A flat portion immediately facing the camera will reflect the camera. Another portion which curves away towards the back will reflect

Fig. 2.—Chromium-plated kettle.

that which is almost behind it—that is, part of the background—and consequently there is a tendency for the edge of this curve to merge into the background. The method adopted to overcome these problems is to surround the object with an evenly lit and uniformly reflecting surface, such as a white card, which will give a uniform reflection from the object. It is then possible to introduce shadows as required. The reflecting surface is carried over the front of the camera and close to it with a suitable aperture for the lens. The difficulty of the object merging into the background is overcome by placing a reflecting surface in contrast with and in the plane of the background, and as near as possible to the outline of the object without cutting the outline. This trouble also occurs with the ground on which the object rests. A lined or figured ground to break the outline is not always suitable, so that some means must be used to suspend the object above the ground. This can be done either by actual suspension or by employing a stand the base of which is smaller than that of the object, and is concealed by it. (See Fig. 2.)

Another problem is to obtain the most pleasing perspective with a high view-point. For this the limit is set by the lens, and here a long focus lens is useful, but excellent results can be obtained by a small sacrifice of normal perspective.

Sometimes in the photography of machinery or parts of machinery it is required to show the difference between metal parts of different colour. This can be done by screens attached to the lens, but a very simple way is to use the celluloid light screens, which can be bought with the Focuslite spotlights.

Technical photography presents some interesting problems. The type of work to be done is the recording of corrosion, staining, faults and defects in castings, and fabricated metal articles, tinplate defects, the results of tests, textures of surfaces, etc. In most of these cases it is just plane surface photography.

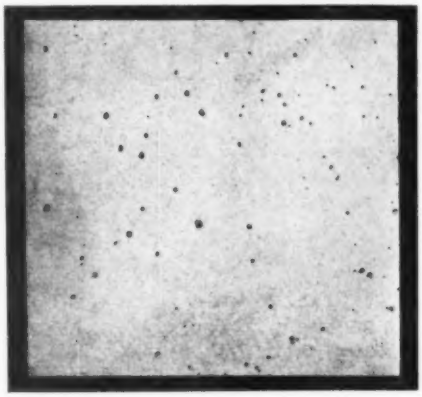
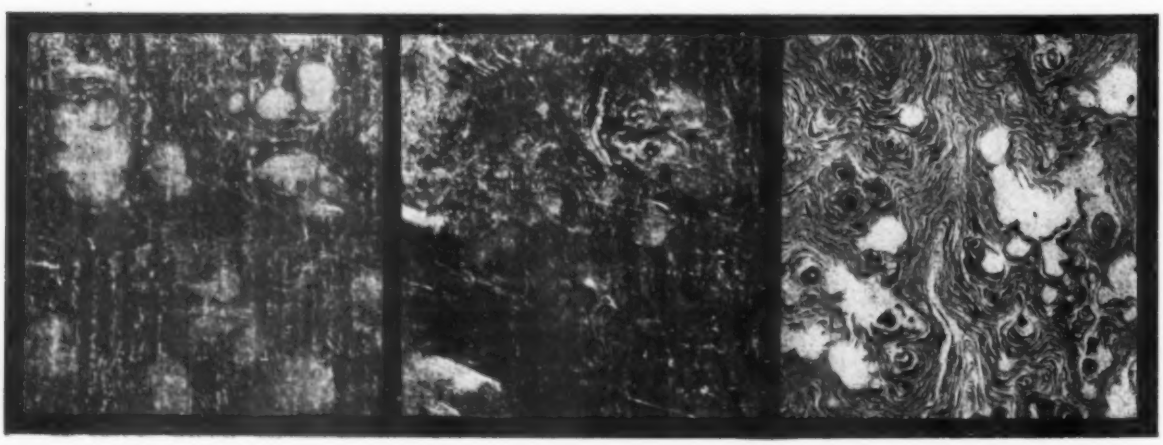


Fig. 3.—Tin-plate specimen tested with hot water. × I.

The recording of rust on tinplate produced by the hot-water rusting test, has been made a routine job by the following method: The specimens are about 3 in. square, and the photographs are required actual size. The front of the camera is covered with a sheet of white card in the centre of which is a hole for the lens. This sheet is evenly illuminated from the front, care being taken that no light enters the lens. The specimen is set up with a black background, either by fixing it to the easel or (if a flat specimen) by putting it behind the glass of a suitable size printing frame, and fixing this in front of the camera. The specimen then reflects the white of the card except where the rust spots are, and these stand out in contrast to the ground (see Fig. 3). If the specimen is placed directly in front of the camera there will be a dark reflection of the lens in the centre of it, so the lens is swung as far to one side as possible, and the specimen is so placed on the easel as to bring the image on the opposite side of the screen. The quarter-plate is mounted in the dark slide, using one of the special adaptors previously mentioned. In this case only the part of the card on the side of the lens opposite the specimen need be illuminated. It often happens that a series of specimens have to be photographed at one time, and the amount of work and material is reduced to a

Figs. 4 and 5.—Specimens of tin-plate showing mottle. × I.

Fig. 6.—Specimen of tinplate, after tin has been etched away, showing origin of mottle. × I.



minimum by setting up two specimens together, and so spacing them that the dark reflection of the lens comes in between them.

The above method is suitable for any highly reflecting flat surface in which it is required to show defects, such as casting defects, blowholes, a machined surface, etc. There is one exception to this, and that is the photographing of defects in tinplate. When a piece of tinplate is examined by the eye it is tilted and turned, each tilt and turn giving a different picture until these collected in the mind form a complete picture. This cannot be done when photographing and it presents a real problem. The solution is found in the use of the long focus lens (the longer the better) in the region of 24 in. to 302 focal length. Actually the lens used for the photographs in Figs. 4 and 5 was a 30-in. telephoto lens, and gave admirable results. The illumination used is slightly oblique, with the lamps close to the camera. The reason for such a long focus lens seems to be very easily understood. We are dealing with microscopic differences in level ranging from 0·0025 in. to 0·00001 in., with very small angles between them. This means that the reflected rays leave the surface at a very small angle to one another, and if the lens is close to the specimen the rays will enter the lens close to one another, giving an image of an evenly illuminated surface. By using a long focus lens and getting well back from the lens these rays will be more separated on entering the lens and will not confuse one another. As these specimens are of the order of 3 in. square it is not practicable to use a short focus lens, getting well back, obtaining a small image, and then enlarging.

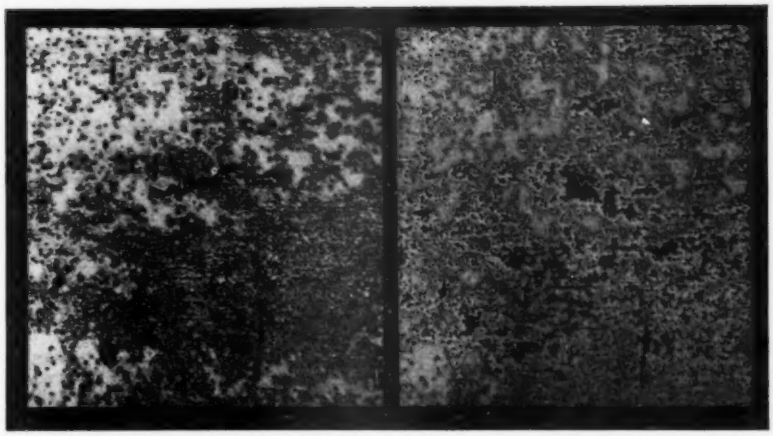


Fig. 7.—Hot-water-tested specimen of tinplate taken on an ortho-process plate. ×I.

Fig. 8.—Same specimen as Fig. 7 taken on an infra-red plate with an infra-red screen. ×I.

Questions of texture and staining are questions of lighting and light-filtering. These present no particular difficulties other than those common to general photography.

Photography.—Exposure is simplified by the general use of artificial light. Choice of plates is not difficult, as there is very little colour in the subjects and high speed is rarely required. On the occasions when a colour difference has to be recorded, it is usually between copper or bronze and a metal of white colour. To obtain a good negative either the subject is illuminated with blue light by putting a blue screen in front of the lamps, or a blue screen is used with the lens, together with a blue sensitive plate, and a contrasting developer.

There is one interesting use of infra-red plates. In the case of tinplate which has been rusted, as mentioned above, the rust on a porous plate tends to form a film over the whole of the surface, thus masking the actual rust-spot site. Apparently infra-red radiation penetrates the rust, and where the rust is only a film is reflected by the tin surface, but is absorbed or obliquely reflected at the actual pore site. Thus the use of infra-red plates locates and distinguishes the rust-spot from the rust film (see Figs. 7 and 8).

Dark-room proceedure is simplified by using as far as possible a standard developer, both for printing and developing. The most important work being photomicrography, a developer is necessary which will give reasonable contrast in this type of negative. Generally speaking, the contrast needs still further increase upon printing, and by adopting a developer of the metol-hydroquinone type these requirements have been met. Increasing the contrast by two stages and not by one action on the plate permits the use of an all-round developer, which gives good bromide prints as well. Printing is carried out on gas-light paper, producing good contrast with blue-black tones.

(To be continued.)

Corrosion-Resisting Centrifugal Pumps

THE advantages of the centrifugal pump, including small size and weight, easy drive by electric motor on the same baseplate, minimum wear and tear, and noiseless running, are familiar knowledge. Modern developments also enable pumps to be constructed of corrosion-resisting materials for dealing with acids, acid water, effluents, and with other corrosive liquids, metallurgical industries, including the pickling of sheets, bars, rods and wire, and electroplating and by-product recovery coke-oven plant.

The construction of such pumps, however, is the work of specialists, and typical of the latest practice are the " CH " and " CHV " pumps of the Pulsometer Engineering Co., Ltd., made in standard sizes from 1½ in. to 6 in. diameter inlet covering a wide range of duties. All the parts of the pump in contact with the liquid are constructed of suitable metals for the purpose, such as stainless steel, acid-resisting bronze, austenitic cast iron and steel, or aluminium alloys, to mention a few examples. These metal parts are mounted on a cast-iron hood, and the impeller is carried on a large diameter steel shaft supported in external ball and roller bearings, protected from contact with the liquid.

In the " CH " pump there is a single inlet impeller of the shrouded type, surrounded by a volute casing, but in the " CHV " pump, which will handle products containing fine solids in suspension, or stringy matter, an open type of impeller is embodied with renewable side-plates rigidly fixed to the casing. These plates are adjusted as required to give proper axial alignment to take up as required any wear if the liquid is abrasive, maintaining the correct clearance and ensuring also that there is little or no pressure on the gland. The casing has an axial suction facing, studded to take British standard pipe connections, whilst the delivery branch is tangential, flanged and drilled, and provided also with a connection for a gauge.

In the standard design the delivery branch is on the left, pointing vertically upwards, with the rotation clockwise when looking towards the suction end. However, any desired branch position is available, either by swinging the casing round or by special drilling. Another good point in both pumps is the very deep stuffing box, the gland also having a condensation connection and channel to dilute and drain off any small amount of liquid that may pass through the stuffing box. Also, there is an auxiliary stuffing box on the gland itself behind the dilution chamber, which may be used for lubrication when diluting is not required. The pump shaft is carried in two substantial bearings, housed in the hood, the driving end having a roller journal bearing, whilst next to the pump is a ball thrust and journal bearing.

In the standard construction the shaft is made of similar material to the pump parts, whilst it can be sleeved at this point in the stuffing box if necessary.

Calcium in Calcium-Lead Alloys

Reference is made to a method for estimating calcium in lead, which consists in casting a test ingot and comparing its surface appearance with the surface appearance of standards. Thus the calcium content is determined by inspection.

IN the manufacture of lead-calcium alloys for cable sheaths, storage-battery grids, and other applications it is desirable to control the calcium content to $0{\cdot}028 \pm 0{\cdot}005\%$ in order to obtain the most desirable combination of properties. Since calcium is a very active element chemically, special manufacturing processes have had to be developed to minimise the contact of molten lead-calcium alloy with the air. Despite the improved techniques adopted, some calcium is always lost and must be replaced, but before this can be accomplished satisfactorily the calcium content of the alloy must be determined.

The usual chemical estimations for calcium are accurate, but, due to the time required for their carrying out, are not entirely satisfactory for plant control. Quantitative spectroscopic analysis methods are more satisfactory, but are also time consuming. In a study of calcium-lead alloys by E. E. Schumacher and C. M. Bouton* to determine a suitable method for estimating the calcium content several methods of attack involving physical, chemical, or electrical properties were considered. The methods investigated included observations of the rate of oxidation or tarnish of freshly cut surfaces using a variety of atmospheres and temperatures, thermal e.m.f. measurements against pure lead, measurements of hardness or strength after various heat-treatments, measurements of electrode potentials in various solutions, the use of various metallographic techniques, and the observation of recrystallisation tendencies after deformation. None of these methods, however, proved adequate, as either the properties involved were insufficiently sensitive to changes in calcium content, or other factors masked the effect of calcium.

In carrying out the experiments, careful observation of the characteristics of these molten alloys revealed no phenomena which varied sufficiently with carbon content to serve as an indication of the composition. When the alloys were chill cast, however, with as little agitation as possible, the surface of the ingots became progressively duller with increasing calcium content to a certain value, and further increase in the calcium content resulted in the fissuring of the surface oxide leaving bright metallic areas exposed. This fissuring phenomenon appeared to be the type of composition sensitive indicator required, as it was shown that when samples of calcium-lead were melted and cast under controlled conditions, the surface markings were reproduced with considerable fidelity in respect to areas of dull and bright surfaces, and that the ratio of these areas was dependent on the calcium content.

Since calcium is readily removed from lead by oxidation, the success of the method adopted depended to a large extent on the details of the melting and casting procedure used for preparing the test specimens. Loss of calcium had to be reduced to a minimum, and fluxes and inert atmospheres, which normally provide adequate protection against oxidation, could not be used as they seriously interfered with the fissuring phenomenon which is the basis of the method of testing.

In carrying out this new method of testing, the procedure adopted consisted in melting in about 2 mins. time a strip of the calcium-lead alloy sheath to be tested in a hemispherical sheet iron crucible about 2 in. in diameter. The broad round shape of the crucible permits it to be tilted until the lip is but a fraction of an inch from the surface of the mould before the metal starts to spout, thus subjecting the stream of molten alloy to only a brief exposure to the atmosphere during pouring. Under the melting conditions described, the casting temperature is controlled sufficiently if the crucible is removed from the flame 3 or 4 secs. after the last portion of the sample has melted. The mould used consisted of a depression 4 in. long, $\frac{5}{8}$ in. wide, $5\frac{1}{2}$ in. to $\frac{3}{8}$ in. deep milled in an iron plate, and gave a test specimen weighing 80 grms. to 100 grms.

Control of the atmosphere over the surface of the metal was found necessary to ensure reproducible results, and for this reason a cellophane enclosed casting chamber was devised. It was found by experiment that both the moisture and carbon dioxide content of the atmosphere influenced the results obtained, therefore it was necessary to remove both chemically and then to reintroduce them in metered quantities to the air passing into the casting chamber. By means of suitable flow meters dry air could be mixed in definite proportions with air saturated with moisture to produce the desired humidity. The most satisfactory results were obtained by casting in an atmosphere having 50% relative humidity and $0{\cdot}02\%$ carbon dioxide. Increasing the carbon dioxide or decreasing the moisture content caused the surfaces to become brighter or vice versa, and provided a few thousandths of a per cent. latituted in adjusting the sensitive range of the method to the calcium content desired. Alloys having calcium contents outside the range of the method were estimated by admixture with known amounts of lead-calcium alloys of known calcium content. Pure lead, in general, could not be used for the dilution as the oxide and traces of impurities present caused loss of calcium.

To date, most experience with the use of this visual test for calcium have been on alloys made with chemical lead substantially free from arsenic, tin, bismuth, iron antimony, and zinc and containing about $0{\cdot}004\%$ nickel, $0{\cdot}06\%$ copper, and $0{\cdot}007\%$ silver. The variations in concentration of these elements in commercial lead has not been found to be sufficiently great to cause serious interference with the indications given by the new test. The method was found to be influenced, however, by certain variations in impurity content which are in excess of those normally encountered. The presence of tin in the order of a few thousandths of 1% caused low indications of calcium content. The use of high purity lead in place of chemical lead had a similar influence. The effects of the interfering impurities can be corrected for, when their presence is known, by varying the atmosphere of the casting chamber or by admixture with known proportions of an alloy having a pre-determined higher calcium content. By such procedures, fissuring was made to occur in alloys that otherwise did not show the phenomenon. In general, sufficient analytical data have been collected to establish the fact that the method discussed is rapid, reliable, and extremely suitable for plant control.

* *Metals and Alloys*, 1941, vol. 14, No. 6, pp. 865–867.

The Aluminium Information Bureau.

THE Technical and Advisory Services of the above Bureau are still available to deal with problems submitted concerning the working, treatment, and application of aluminium and its alloys. The Bureau has removed to new premises at 109, Jermyn Street, London, S.W. 1. (Telephone: Whitehall 5411.)

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Raw Materials and Salvage

RECENT events in the Pacific not only threaten the military and naval fronts, but also many economic aspects of our war effort. From that part of South Eastern Asia most directly involved in war with Japan comes 99% of the world's rubber—53% from British Malaya, India, Burma, and other British possessions, 39% from the Netherlands East Indies, and 7% from Indo-China and Thailand. Approximately 75% of the world's tin comes from the same area, which also possesses rich petroleum resources. In addition, Japanese naval activity in the Pacific may well interfere with deliveries of other vital commodities.

The serious nature of the economic situation was immediately brought home to the people of Britain and its Allies by the prompt action of their Governments in restricting the sale and processing of rubber. Few modern means of transportation, either civil or military, can function efficiently without rubber, and our available resources must be conserved for use by our armed forces and essential industrial transportation. The ordinary citizen must relinquish all claim to such a vital necessity, and he will undoubtedly find other products under severe control in the very near future.

Reduction of civilian consumption is not the only contribution that can be made by the ordinary citizen. He can contribute in a more direct manner by increased activity in the important work of salvage. The collection of waste materials is, of course, not merely a war-time activity; it is an important business at all times. In the case of metals, for instance, with very few exceptions, and these are a relatively small part of the metals used, they can be reclaimed. Thus, conservation in the use of metals can be achieved by the constant use and re-use of that part of production which is not destroyed in service, and the recovery of scrap and wastes and their use with or instead of metals produced from ores, is sound economics, and entirely in accordance with the general principle of conserving natural resources. Many countries, including our own, have been, and in some respects still are, very extravagant in the use of raw materials; in the present emergency, however, waste materials must replace, rather than supplement, ordinary sources of supply.

Because of a number of factors, the use of scrap materials, apart from scrap iron and steel, was not large in normal times in this country, though it must be admitted that considerable progress had been made with a view to conservation of supplies. It is probably true that our relatively high standard of living, the very prodigality of our ordinary way of life will result in an unexpected harvest of scrap materials which can be brought into service. There can be few homes where some metal scrap is not available, and it should be a personal job to root it out and take steps to bring it into immediate re-use. While this will rapidly increase our collection and use of materials long regarded as junk, there are very few works up and down the country which could not greatly accelerate supplies. Who, in industry, is not familiar with the graveyards that exist in so many works, in any one of which tons of material should become available for re-use in an emergency of this kind. An intensive campaign is now under way to restore a large part of this scrap to valuable use in machinery and tools of war.

The collection of iron and steel is at present the principal objective of the scheme recently put into operation, but it is by no means the only objective. A nation-wide campaign for the collection of scrap metals of many kinds has been in progress for some considerable time and will continue at least until the end of the war. A special drive for aluminium has been successfully undertaken, and the collection of copper, brass, lead, zinc and other non-ferrous metals is continuous. All these metals are essential to our war effort.

With the ever-expanding metal requirements, the need for the conservation of supplies has become very real, and common sense as well as economic necessity has indicated more prudent use of the ores available, without waste or needless destruction. It has been realised that since metals are, to a large degree, indestructible, the process of mining, smelting, and refining merely results in a transfer of metal resources from the depths of the earth to the surface, and that the stock of metal in use, or that part which has been in use but has ceased to be serviceable for the purpose it was originally intended, is no less a valuable resource than unmined ore. Not only does the contribution of scrap metal relieve pressure upon our material resources, but it affords a great economy in time and labour. In the case of steel, for instance, the use of scrap increases output and is accompanied by an additional economy in operation of furnaces. The use of iron ore alone not only involves increased mine production, but greatly increased transport facilities and great fuel consumption to extract the metal. It is noteworthy, for instance, that in the case of aluminium it has been estimated that 1 lb. of scrap aluminium recovered means 11 kw.-hours of electricity saved. Thus, it will be appreciated that in addition to time and labour the re-use of metal effects a great saving in fuel and power.

One question in connection with the salvage of scrap metals frequently arises in the minds of many people: that concerning the large number of tin cans which form a substantial part of household salvage. When metals are scarce and particularly now that tin supplies are threatened, it is naturally expected that some effort is made to recover the waste tin from these cans. This is probably the only section in which tin is going to waste in this country, although the subject is under careful study. So far, it has not been regarded as economical to collect and transport tin cans for de-tinning, and it is doubtful whether any de-tinning of this form of salvage will be carried out unless and until an emergency in the supply of tin renders it imperative to conserve tin without regard to the cost. As far as is known, only one firm in this country has made it its business to de-tin such cans. At present the cost of collection and transport of used cans for de-tinning is prohibitive. Clean tinplate trimmings and stampings from the manufacture of cans is, of course, always de-tinned, and the iron and tin recovered are re-used.

The difficulty with used cans is chiefly an economic one. They are recovered by local cleansing authorities, and it is a common

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "Metallurgia" should not be taken as an indication that they are necessarily available for export.

practice to compress or bale them along with any other form of ferrous metal scrap and sell the bales to iron and steel works. In this way the iron is recovered, but the tin is lost. The price of this form of baled scrap is about £1 per ton less than for ordinary steel furnace scrap, and there is not the economic incentive to de-tin. At present about five firms in this country are engaged in de-tinning, and the processes are well understood and working quite satisfactorily. The difficulty is that they have to handle 99% of light steel scrap for about 1% of tin, and the economics of the process are bound up with the different prices obtained and with the transport charges involved between the source of supply, their works, and the steel furnaces.

While there is apparently an excusable waste of tin in the distruction of tin cans, the cost of recovery is so high that it would only be feasible in the face of the gravest emergency. Roughly, about eleven to twelve thousand tons of tin per year are used in the manufacture of tinplate, much of which is used in this country, and in addition a considerable amount of tinplate arises from imported canned goods. Although the position regarding the recovery of tin from tin cans is difficult, it will be appreciated that an industry based on secondary tin has long been in operation in this country. Probably the largest item of scrap supplying this industry is used railway bearings and similar supplies of babbit metal; these are converted into solders and new bearings.

In all works a workable procedure should be developed, in co-operation with each department, to collect and deal with cuttings, turnings and borings: it is at the works that these can be more easily separated and waste metal containing alloys can be sorted out with a view to conserving alloys that are becoming increasingly difficult to obtain. Quite apart from a better recovery of valuable alloys in this way, the economic aspects make it worth while. Particular attention should be directed to the reclamation of tool-steel materials, parts of discarded fixtures, and other such sources. Salvaging these materials, which contain a high percentage of tungsten, will reach an appreciable amount in the course of a few weeks, and, if they are segregated as tool-steel scrap, producers of high-speed steels would welcome it at a fair price.

While it is true to say that real conservation of metals can be achieved by the constant use and re-use of that part of production which is not destroyed in service, the prudent use of natural resources, and the efficient use of combinations of metals in the form of alloys, should not be overlooked, since they too contribute in the conservation of metals. There is no justification for waste in peace-times, and certainly none for the extravagant use of raw materials and in this time of emergency it should be regarded as a sin. The metallurgist has given the engineer new and improved materials capable of bearing greater strain, giving longer life and resisting more and more successfully the ravages of corrosion. As one alloying constituent becomes difficult to obtain, the use of other elements is developed with a view to maintaining high efficiency in service from the materials produced. An instance of this is high-speed steel, for which it has been customary to use a high percentage of tungsten: difficulties have been encountered in the transport of this material from China, and, to some extent, it is being replaced by molybdenum, without detriment to the service of the steel.

Many such examples could be cited, the main point is, however, that an important factor in the conservation of metals concerns close co-operation between the metallurgist and the engineer. It should be a sin to disregard the discoveries and developments of the metallurgist in providing new and improved metallic alloys, which produce greatly increased strength, give longer service and resist more successfully the dissipative effects of atmosphere, chemical contact, high temperatures, etc., than the materials in more general use. Thus, in addition to the salvaging of scrap, this latter aspect of conservation offers considerable scope for the less extravagant use of metals.

The Supply and Training of Welders

THE Ministry of Labour Training Centres, the largest organised training authority under centralised control, have completely reorganised their welding training in accordance with recommendations put forward by the Institute of Welding. The training under the revised scheme gives a carefully graded course of instruction founded on basic principles, and arranged to provide the welder with a sound understanding of the operations and technique which he is required to master. The Centres have a training capacity of 700 places, of which 320 are for arc and 380 for gas welding. Operating on a three-shift system, it is therefore possible to train 5,000 welders per annum for all requirements.

The Training Centres are prepared to provide trainees or to give training in the following groups:—

(*a*) Single purpose welders (downhand only) for mass production welding operations.

(*b*) Specially trained welders for specific welding operations.

(*c*) Men or women provided by the welding employer for training in specific welding operations.

(*d*) Trainees who have received the complete syllabus of training and who have passed the full series of proficiency tests for general work.

Under group (*a*) arc welders receive basic training in mild steel welding of all type of joints (downhand only) in plate thicknesses from $\frac{3}{16}$ in. to 1 in. Gas welders receive similar training in plate thicknesses from 20 S.W.G. to $\frac{1}{8}$ in., and this range is also covered by carbon or metallic arc processes for arc welders.

In group (*b*) the training may cover welding in all positions not only in mild steel, but in high-tensile, stainless, and other commercial alloy steels, together with the welding of non-ferrous sheet and plate—i.e., aluminium, copper, monel, brass and other alloys in either the arc or gas processes. In addition, the welding of thick and thin walled tubing is taught.

Group (*d*) covers those trainees who, by possessing special aptitude to benefit by a longer course of training, have been successfully passed through graded courses to reach the required state of proficiency in the given section.

In order that the fullest and most efficient use may be made of the training facilities provided, the Ministry of Labour is anxious to have the close co-operation of employers of welding labour. It is requested that employers likely to require welders from Government Training Centres will notify their probable requirements to the Regional Office of the Ministry of Labour, in order that the probable demand, both as to number and type of training required, may be estimated. The managers of the Centres will welcome discussions with individual employers on their requirements.

The period of training under war-time conditions cannot provide the background of experience required for production work in industrial workshops, and it is important that employers should collaborate by providing conditions which will favour a rapid assimilation of this background. Sympathetic guidance during a preliminary period is necessary; but provided the limitations of the newly trained welders are acknowledged, the trainees should prove quite satisfactory for the majority of welding operations.

The Institution of Engineers and Shipbuilders in Scotland.

ON behalf of himself and his brother, Mr. G. T. Marriner has generously endowed an annual award in memory of his father. The award will be known as the "W. W. Marriner Premium," and will consist of books or instruments to the value of £5. It will be regarded as the highest award normally made; for papers of exceptional merit, a gold medal may be awarded in addition to the "W. W. Marriner Premium."

Practical Examination of the Corrosion Resistance of Light Alloys*

By G. O. Taylor

Corrosion problems are frequently encountered in connection with the use of light metals and the need for conducting tests to determine corrosion resistance of a particular alloy under service conditions is of great importance. Practical methods for the examination of corrosion resistance of light metals, described in this article, provide workers with a testing technique which can be standardised to produce reliable results.

Automatic Intermittent Wet and Dry Test Apparatus

In the "sea-mist" test there is a tendency for the corrosive action on the specimens to be more concentrated on the lower half, where drainage takes place, than on the top half. To avoid this concentration, which can have undesirable effects (particularly where test bars for determination of mechanical properties after corrosion are concerned), it may be necessary to reverse the test pieces every two or three days to ensure a more even distribution of attack. The apparatus shown in Fig. 5 was designed to provide a constantly changing point of drainage on each specimen by automatic means, and at the same time to provide a procedure from which the human factor was eliminated once the test had started.

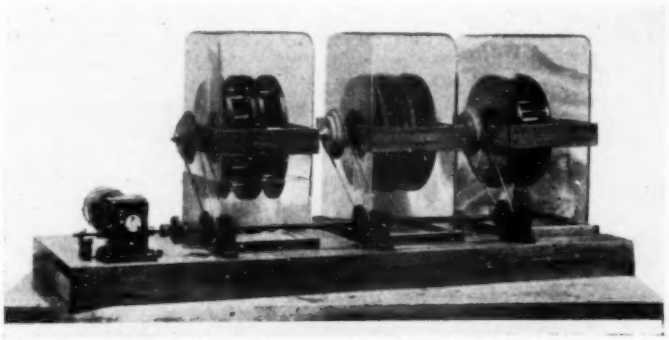


Fig. 5.—Automatic intermittent wet and dry test apparatus.

Essentially, the apparatus consists of a number of machined bakelite discs rotated by a countershaft driven by a spring belt from a main shaft connected directly through a flexible coupling to a geared low-speed motor. This arrangement enables smooth rotation of the discs at speeds down to as low as six revolutions per hour. The shaft and pulley wheels of anodised "Birmabright" aluminium alloy rotate in "U"-type bearings, so that the entire assembly of discs may be removed from the machine in a few seconds.

The bearings are located on a varnished hardwood frame lodged on the top of a stout glass tank, and a second glass tank lodges in the reversed position in a recess in the frame to provide a dustproof apparatus, which allows visual examination of the test specimens at any period of the test without stopping the rotation or disturbing the assembly.

The lower glass tank is partially filled with 3% sodium-chloride solution, or other corrosive media, to a height such that for one minute in every ten each specimen is completely immersed in the solution, and then drains and partially dries during the remaining nine minutes of travel in air till it reaches the solution again. The manner in which automatic changing, both of point of drainage and also of contact points is provided will be seen by reference to the details shown in Fig. 6.

*Continued from page 66, January issue.

The bakelite disc A is provided with a number of diametrically opposed tapered holes B. Backing the disc on the side of the greater diameter of the holes B, but spaced from it at a distance of $\frac{1}{32}$ in., is a second disc of "Birmabright" aluminium alloy sheet, anodised and stove-enamelled. A pair of such discs are mounted on the countershaft D, with the lesser diameter of the holes B facing each other and coincident. If now a cylindrical type test piece E is lodged in a pair of coincident holes and allowed some freedom of movement sideways, as shown, then when the discs are set in motion the test piece itself rotates around the periphery of the hole E, since it must always rest at the lowest point of the hole B, and this point is constantly changing during rotation of the disc.

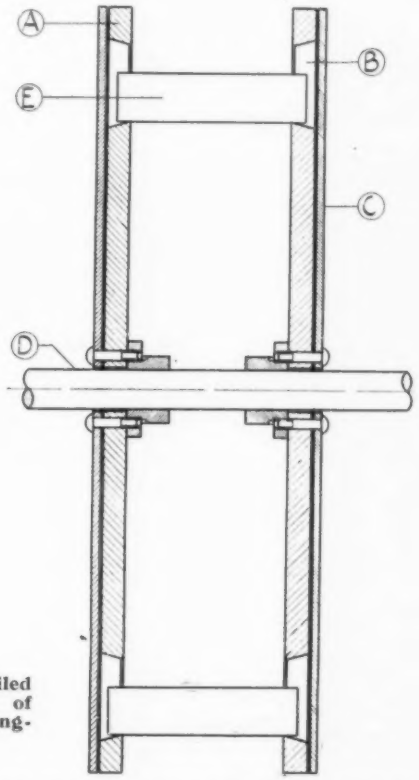


Fig. 6.—Detailed arrangement of automatic changing method.

Not only does the test piece thus rotate constantly to provide a fresh point of drainage (as any droplet of solution forming tends at once to be flattened out into a film of moisture again), but due to such rotation on two sharp edges there is some side-to-side oscillation, so that the point of contact or suspension never remains constant. Any droplets of moisture collecting at the ends of the specimens drain away through the space provided between the disc and the backing plate. Since there is no concentration or corrosion at drainage points, and no concentration of action

at the points of support, the apparatus thus automatically provides equality of corrosive conditions over the entire surface of each test piece, and, furthermore, ensures that all test pieces are treated exactly alike.

While the apparatus is primarily designed to take cylindrical test pieces of different lengths and diameters up to as large as standard B.S. type test bars, it can also be used for testing sheet or strip if the tapered round holes are replaced by tapered slots, as indicated in Fig. 7. If the disposition of the test pieces in relation to diameter or width is studied before the apparatus is set in rotation there is no drainage from one specimen on to others below, although it may be necessary in the case of large bars or wide sheet to achieve this by employing only alternative slots or holes.

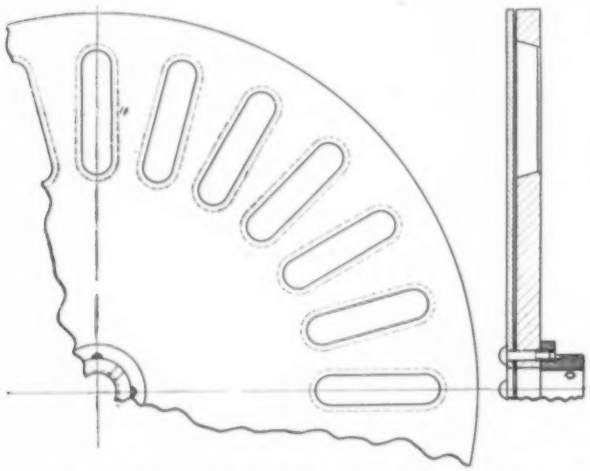


Fig. 7.—Modifications for testing sheet or strip.

While the automatic apparatus described is relatively expensive to make chiefly on account of machine-tool hours required, particularly in preparation of the bakelite discs the consistency of results obtained and the fool-proof nature of operation render the investment well worth while.

Furthermore, it is of "universal" usage, as it will accommodate many types and sizes of test pieces, so that it is possible to determine with the highest degree of accuracy relative losses in weight, deterioration of mechanical properties on either tensometer type or full-size B.S. test bars, and to conduct the examination of the relative values of protection that may be gained from applied coatings or surface treatments.

When the test pieces have been assembled into position the apparatus requires no attention other than to calculate the approximate number of hours when a given number of motor revolutions will have been attained, and to stop the motor when this number is indicated on the tachometer.

"Master Specimen" System of Correlating Results

In a corrosion investigation, which may be spread over several months in various steps, the *rate* at which the salt solution will attack the test pieces will to some extent be influenced by fluctuations in room temperature. Unless a temperature-controlled room is used for housing the testing apparatus, or unless elaborate arrangements are made for thermostatic heating and cooling of the test solution to maintain it at a constant temperature, some variation in degree of action on two specimens, both taken from the same test bar, but tested at different times in the year, will be experienced.

The following system was therefore devised to enable results taken at one period in the year to be compared with results taken at another period, without the necessity for temperature control of the test room of the test solution itself, and the results obtained over a long period have shown a high degree of accuracy.

The method comprises the preparation of a set of "master" specimens of standard size and shape. If the investigation, for example, is on a series of wrought alloys, then the master specimen may be of high-purity aluminium sheet, and a single sheet of this metal, say 2 ft. × 2 ft. should be set aside to be used solely for "control" purposes.

Three specimens from this sheet are included in each test carried out, and the loss in weight per square centimetre of surface area when determined at the end of the test is, in the case of the master specimen, regarded as being unity. Taking as an example the case of three wrought alloys, A, B and C, for which the losses in weight in milligrams/square centimetre of surface area per 30 days were determined as 30, 25 and 15, respectively, while the master specimen lost 20.

Then the relative resistance to corrosion of the alloys may be expressed as follows:—

Alloy C ..	0·75	The lower the figure, the higher the resistance to corrosion.
Master ..	1·0	
Alloy B ..	1·25	
Alloy A ..	1·50	

Now assume that at a later date two more alloys, D and E, are tested, and the losses in weight, as before, are determined as 30, 40 and 24 for the master specimen.

Then the relative resistance may be expressed:—

Master	1·0
Alloy D	1·25
Alloy E	1·66

By comparison of the results, it will now be possible to say that alloy D is as good as alloy B, but that E is inferior to A in the ratio 1·5 : 1·66, or, in other words, E tends to corrode 1·16 times faster than A.

If it is necessary to carry on an investigation after the stock of "master" specimens has become nearly exhausted, correlation can be continued by carrying out a separate test in which the new stock of "master" metal is compared with the old and a suitable factor arrived at. The choice of metal for the "master" specimens must be decided by the worker, with consideration to the specific requirements of his case, and it is obvious that the same form should be used. That is, sheet should be used in the case of an investigation on sheet alloys, and extrusion in the case of extruded alloys, etc.

Preparation of Test Specimens

If reliable results are to be obtained a standardised routine for the preparation of specimens must be followed. The methods to be employed can best be worked out in detail by the investigators, but the following outline will serve as a guide.

"Loss in Weight" Test

The specimens should all be exposed to test in the same surface condition—i.e., all specimens should retain the as-manufactured surface, or should all be machined to a smooth finish.

(*a*) For tests on cast alloys, standard 1-in. diameter test bars, either sand- or chill-cast, as may be necessitated by the requirements of the case, should be machined to produce from each bar two lengths 3 in. long by $\frac{3}{4}$ in. or $\frac{1}{2}$ in. diameter. If it is desired to retain the as-cast skin, the bars should simply be cut 3 in. long with the hacksaw and filed square at the ends. Any necessary identification markings should be stamped on the ends.

If the rotary type apparatus is used no further work is necessary, but if constant immersion or spray apparatus is used, it will be necessary to drill a hole to take a glass hook at a standard distance from one or both ends of the specimen.

The test pieces should be degreased in an organic solvent and then heated to 100° C. for a short time to drive out any moisture that may be in the "pores" of the metal, before weighing and recording the total surface area. It is important that after the initial degreasing, specimens should not be handled except with the tongs. Any form of surface treatment, such as anodising or chromating,

should be given after degreasing, and prior to drying and weighing.

At the conclusion of the test, after observations have been made on the type of corrosion that has occurred, the corrosion products should be removed in the case of aluminium alloys by placing the specimens in 10% pure nitric acid solution at 60° C. for such time till effervescence ceases, followed by swilling in cold water and cleaning with a brittle brush. This will be found to remove completely the corrosion products with but negligible attack on the metal itself in most cases, but where attack may be suspected a factor for error can be deduced by placing a weighed blank in the acid solution for the same length of time. Errors involved in removal of a surface treatment may be compensated for in the same manner.

In the case of magnesium-base alloys, the corrosion products may be efficiently removed by allowing the specimens to stand overnight in cold 20% caustic-soda solution and then treating in boiling 10% potassium-dichromate solution, followed by bristle brushing in running water. In the case of severely attacked magnesium alloy specimens this operation may need to be repeated before all corrosion products are completely removed. After cleaning, specimens should be swilled with distilled water, dried at 100° C. for 15 minutes, and weighed after cooling in a desiccator. The loss in weight is then expressed in terms of milligrammes per square centimetre of surface area.

(*b*) Extruded specimens should preferably be of $\frac{3}{4}$ in. diameter round rod, and after parting to length should be left in the as-extruded condition. Otherwise the procedure is as for cast specimens.

(*c*) Sheet specimens should be sheared oversize and then filed down to either 3 in. × 2 in. or 6 in. × 2 in., with the major dimension in the direction of rolling of the sheet. The as-rolled surface should preferably be left intact unless it is necessary to remove it for a specific requirement of the test. Identification marking should be carried out in the top right-hand corner of the specimen, otherwise the procedure is as for the cast specimens.

Determination of Loss of Mechanical Properties

For determination of loss of mechanical properties at least 15 tensile test bars of each alloy are required. Some investigators prefer to shape the tensile test bars oversize and machine down to actual dimensions after corrosion has taken place. But as a criterion of what may be likely to happen under actual service conditions, it is probably better to shape the bars to actual size before the test. According to the amount of material available, the bars may be either of tensometer type or to the full size specification.

Three bars are tested (before the corrosion test commences) to establish the initial mechanical properties, and then three more bars are "pulled" at intervals of two, four and six months. The remaining three bars are greased and the mechanical properties determined at the end of the test as a check on the possibility of changes due to ageing. According to the deterioration of mechanical properties that is observed, the broken bars may, or may not, require to be metallographically examined for the detection of the possible presence of intercrystalline corrosion. The results achieved can with advantage be graphically illustrated.

Testing of Organic Surface Finishes

If the specimens are to be finished with an organic system it is necessary to weigh them three times prior to the test—(*a*) after the initial degreasing, (*b*) after the application of the priming coat or coats, and (*c*) after the application of the finishing coat. By this means the weight of the finishing system per square yard of surface can be calculated, and it is possible to verify that approximately the same weight of organic protection has been applied to each specimen. At the conclusion of the test, wash the test plates well under the tap and rub gently with the fingers to remove cracked and blistered paint. Dry carefully and photograph for permanent reference. When the photographic proofs have been passed as satisfactory, remove the organic finish by any suitable means which will not attack the underlying metal, then carry out the appropriate corrosion-product removal procedure, and calculate the loss in weight of the test plate in milligrammes per square centimetre of surface area.

Unless otherwise required for a specific purpose, the testing solution should, preferably, be of a 3% solution of pure sodium chloride in distilled water. Some workers may prefer to use a 20% solution, but it is necessary with this more-concentrated liquid to give more attention to the jets in the "sea-mist" apparatus to avoid clogging by salt.

In all tests at least three specimens of each metal should be exposed simultaneously, so that if one specimen should show an erratic result the cause may be sought for, and if found to be due to an experimental error it can be discarded and the average result of the two consistent specimens be taken as the corrosion value.

High-speed Steel

IT is likely that in the very near future a major change will be made in the composition of high-speed steel, since the tungsten content may be limited to 6·5%, except for a small quantity of special purpose steel. The 6% tungsten-6% molybdenum steel is now recommended as the best substitute for 18-4-1 high-speed steel. Much experimental work on this steel was carried out by Joseph Gillott and Sons in 1940, and data concerning this "Six-Six" type of high-speed steel was published at that time, giving the results of this important development. Since then this firm has supplied many tons of this steel and in order that it may be given a trial, a small supply in tool lengths of the following sizes are available:—$\frac{11}{16}$ in. and $\frac{13}{16}$ in. diameter; $\frac{1}{2}$ in. and $\frac{3}{4}$ in. square; 1 in. × $\frac{5}{8}$ in. flat; $4\frac{1}{8}$ in. diameter × $\frac{5}{8}$ in. thick blanks.

These samples will be supplied gratis on application to Joseph Gillott and Sons, Lambert Street, Sheffield.

Common Errors in Precision Grinding

So much progress has been made in the manufacture of grinding wheels in recent years that, nowadays, grinding troubles are usually due to unknown variables, such as the condition of the grinding machine, skill of the operator in manipulating the wheel, and even to the operators' psychological reaction. It is the unknown quantities which require expensive time-consuming experimentation. Often they are plainly visible to one who knows what to look for. But too often they are ignored, and a solution of a grinding problem is sought in a specially made wheel of special characteristics. A little book has been published recently dealing with grinding faults, which explains how many a grinding problem can be solved without recourse to specially made wheels. Copies are available on application to the Carborundum Co., Ltd., Trafford Park, Manchester, 17.

Official Specifications for some Nickel Alloys

THIS publication contains summaries of the chief specifications used for nickel alloys, including Monel, K Monel, Inconel, Cupro-Nickel and Nickel Silver. The properties of the high nickel alloys are given in an appendix.

Copies may be obtained, free of charge, from Henry Wiggin and Co., Ltd., Grosvenor House, Park Lane, London, W. 1. Individuals are requested to give the names of their firms or otherwise indicate the nature of their interest.

Electrolytic Manganese and its Alloys

Developments in the manufacture of electrolytic manganese have resulted in a comprehensive programme designed to study alloys with this purer form of manganese. This article is confined to a summary of the properties of manganese-copper, manganese-nickel, manganese-copper-nickel, and aluminium-manganese, resulting from the investigations in which electrolytic manganese was used.

IN the development of new metallurgical processes to the point where private interests are willing to make a real effort to determine their practicability, it has proved necessary to demonstrate definite outlets for the products of such processes. A good example is furnished by the process developed in the Metallurgical Division of the United States Bureau of Mines for the production of electrolytic magnesium. A rather comprehensive programme of alloy investigation has been initiated, and are centre port* contains the results of studies on the potential value of various manganese alloys. It is primarily concerned with the manufacture of electrolytic manganese and of its alloys with copper, zinc, copper and zinc, nickel, copper and nickel, aluminium, iron, and iron and chromium. The report is very comprehensive, and reference to only a few of the results of this work can be given in this summary.

Properties of Manganese-Copper Alloys Made with Electrolytic Manganese

The electrical resistance of the alloys of manganese and copper has been reported by Dean and Anderson.[1] The results show that the electrical resistance of the alloys quenched from temperatures near their melting-point are related to composition substantially as would be expected for a series of solid solutions. The relationship is shown in Fig. 1. Closer examination of this curve indicates a linear

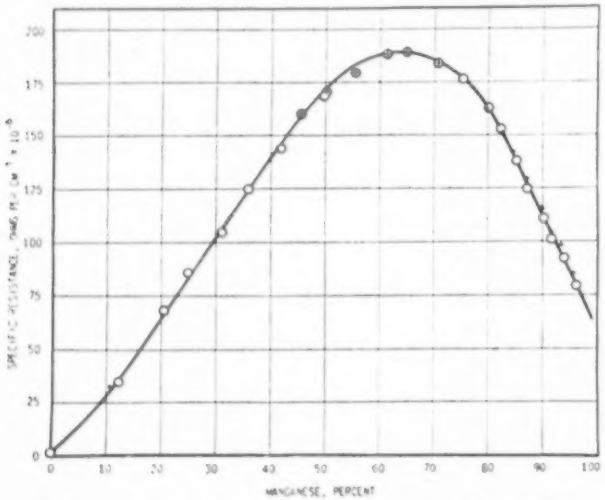


Fig. 1.—Specific resistance of manganese-copper alloys in quenched condition.

relationship between composition and resistance in the two ranges of composition from 10 to 40 and 82 to 96% manganese. It is unusual to find a linear relationship between weight-per cent. and electrical resistance, and doubtless this relationship results from the fact that the atomic per cent. of manganese divided by the density is a linear function of weight-per cent. within the range of composition considered. Thus it appears that plotting weight-per cent. is merely a convenient method of showing the relationship between the percentage of manganese atoms by volume and the electrical resistance. For the slow-cooled alloys of manganese and copper the relationship between composition and electrical resistance is very different.

Up to approximately 40% manganese there is no difference in resistance between the quenched and slow-cooled alloys. Above 40% manganese the resistance of all alloys containing less than 90% manganese is lower for slow cooling than for quenching. The resistance drops with changes in composition from 40 to 90% manganese. The drop is not uniform, but appears to be somewhat step-wise. A complete explanation of the lower resistance of the slow-cooled alloys ranging in composition from 40 to 90% manganese is not yet available. Studies of the X-ray structure, however, indicate that the drop in resistance is accompanied by a definite change in the lattice parameter of a given alloy, but there is no change in the crystal structure nor does a second phase appear. Probably the lowering of electrical resistance may therefore be traced to an ordering of the manganese and copper atoms in the lattice. With alloys containing less than 40% manganese, there is no change in electrical resistance with any type of heat-treatment.

Alloys between approximately 40 and 70% manganese are reversibly affected by heat-treatment—that is, the same electrical resistance is obtained by slow cooling the alloys to 600° and quenching as by quenching the alloys and reheating to 600°. Above 70% manganese this revers bi'ity is lost, as a much higher resistance is obtained by quenching and reheating the alloys than by slow cooling them from nearer the melting-point to a given temperature and quenching. This higher resistance undoubtedly results from decomposition of the solid solution on reheating, which apparently does not take place unless the alloys have first been subjected to reheating at a low temperature. Again, the exact explanation is not yet available, but it is suggested that the alloy must be brought into an ordered state before it will decompose.

Alloys containing more than 90% manganese attain a high electrical resistance by either reheating to temperatures between 500° and 700° or slow cooling to these temperatures and quenching. With very high (98 or 99%) manganese alloys high resistances frequently have been noted by quenching rods of these alloys and reheating them to successively higher temperatures with intermediate quenches. These very high resistances apparently result from low-temperature decomposition of the alloys brought about by strains introduced in quenching. The same procedure applied to fine wires does not give as high a resistance as that obtained with rods.

The hardening of copper-manganese alloys by cold work and heat-treatment has also been reported by Dean and Anderson.[2] The relationship between composition and hardness of the quenched alloys and the quenched and cold-worked alloys is indicated in Fig. 2. Fig. 3 shows the hardening of these alloys by heat-treatment. It will be noted that the alloys containing less than 40% manganese do not show an appreciable hardening with heat-treatment. Alloys containing more than 40 and less than 70% manganese begin to harden at 450° and reach a maximum hardness at 500°. They soften progressively on heating to temperatures above 500° and fall to virtually their initial hardness at 800°. This hardening therefore corresponds to the drop in electrical resistance and the decrease in lattice parameter; it is a reversible phenomenon and

* Bureau of Mines Report of Investigations 3580.

1 Dean, R. S., and Anderson, C. T. "The Alloys of Manganese and Copper." I. Electrical Resistance.) Presented at October, 1940 meeting of American Society for Metals, Cleveland, Ohio. Not yet published.

2 Dean, R. S., and Anderson, C. T. "Alloys of Manganese and Copper" (III. Hardening by Cold Work and Heat treatment.) Presented at October, 1940, meeting of American Society for Metals, Cleveland, Ohio. Not yet published.

probably is connected with an order-disorder transformation. Alloys containing more than 70% manganese show an irreversible increase in hardness when heated to temperatures of 600° and above, which is clearly due to a decomposition of the solid solution.

From a practical standpoint, the most interesting property of the copper-manganese alloys is their vibration damping capacity. Studies of the vibration damping capacity of these alloys at low stresses, including a description of the method of measurement, have been reported by Dean, Anderson and Potter.[3] Alloys containing less than 40% manganese do not show exceptionally high-damping capacity with any heat-treatment. All alloys containing more than 40% manganese may attain unusually high-damping capacity by suitable heat-treatment. A graph

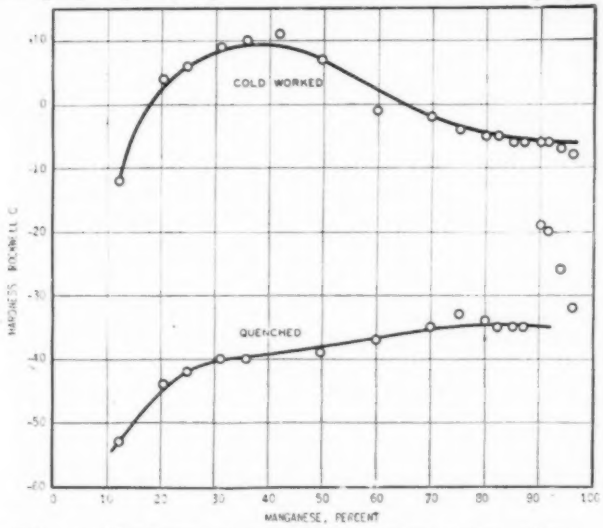


Fig. 2.—Hardness of manganese-copper alloys after quenching and cold-working.

shows the damping capacity obtained by quenching the alloys from near the melting-point and reheating them to various temperatures. The figure shows that the damping capacity is maximum when the alloys are reheated to a temperature of 450°; higher temperatures result in a rapid drop in damping capacity, especially for alloys containing between 40 and 70% manganese. For alloys higher in manganese the highest damping capacities are obtained by slow cooling. An alloy of 80% manganese slow-cooled from approximately 900° C. shows a damping capacity of 13%; the tensile strength of such an alloy will be about 75,000 lb. per sq. in., the elongation about 25, and per modulus of elasticity approximately 12×10^{11} dynes the sq. cm.

A study of the microstructure of alloys of this series has been reported by Dean, Anderson and Jacobs.[4] As a result of this study the equilibrium diagram shown in Fig. 4 has been suggested. According to this diagram the epsilon phase, which is stable up to 450° between 40 and 90% manganese, is responsible for the high vibration damping capacity of alloys that have been slow-cooled or slow-cooled and reheated to temperatures up to 450° C. The quenched alloys, which also show high vibration damping capacity with more than 70% manganese, presumably owe this property to the preservation of the gamma solid solution. As stated, the epsilon phase is thought to differ from the delta and gamma phases of the same composition only by the ordering of the manganese and copper atoms.

One of the most interesting features of the microstructure of these alloys is the so-called block structure. In the tentative equilibrium diagram this structure is regarded as a mixture of the delta and gamma phases, which have identical lattice parameters. In other words, this structure represents a partially disordered distribution of manganese and copper atoms in the lattice. Why a partially disordered lattice should have a structure of this type is uncertain. Apparently it occurs, however, in other systems in which order-disorder transformations are taking place.

Alloys of Manganese and Nickel made with Electrolytic Manganese

All the alloys of manganese and nickel made with the electrolytic metals are ductile with the exception of those near MnNi in composition and those containing more than 95% of manganese. The manganese-nickel and the manganese-copper system of alloys have many similarities. When quenched from a temperature near their melting-point, the manganese-nickel, like the manganese-copper

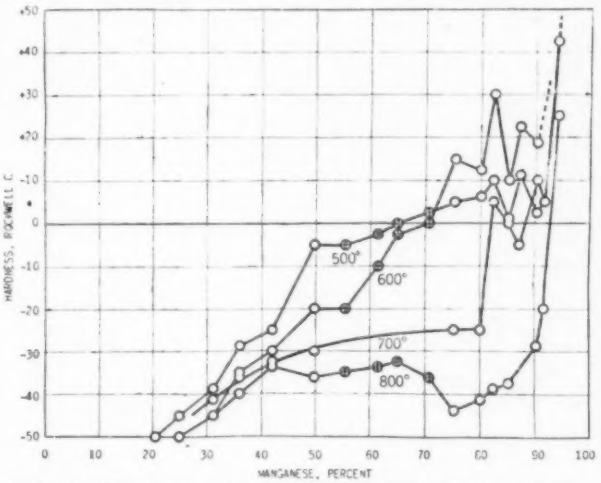


Fig. 3.—Hardness of manganese-copper alloys after quenching and reheating to various temperatures.

alloys, appear to be simple solid solutions. Their properties, however, change greatly with heat-treatment. Slow-cooled alloys of manganese-nickel possess high vibration damping capacity between approximately 75 and 95% manganese. In the same range of composition, these alloys possess an abnormally high coefficient of expansion. Alloys containing approximately 65% manganese have substantially zero temperature coefficient of electrical resistance, together with an electrical resistance of more than 190 microhms per centimetre cubed. All of these properties suggest possible practical applications of the manganese-nickel alloys; however, most of the properties are enhanced in the ternary alloys of manganese, copper and nickel.

Ternary Alloys of Electrolytic Manganese with Copper and Nickel

This ternary system contains many alloys offering great promise of practical utility. One of the most interesting groups of alloys in this system is the group whose composition approaches the pseudo binary system, Cu–MnNi. When these alloys are quenched from approximately 900° C. they are relatively soft; however, when alloys containing more than approximately 12½% of either manganese or nickel are reheated to temperatures from 425° to 450° C., they undergo considerable hardening. The accompanying table from a paper by Dean and Anderson[5] shows the effect of various temperatures of heat-treatment on the amount of hardening of the alloys. In view of the low heat conductivity of these alloys, it is possible to bring about local softening of the hardened alloy and thus produce any desired combination of hardness and toughness in a die or other object made of the alloy.

3 Dean, R. S., Anderson, C. T., and Potter, E. V. "The Alloys of Manganese and Copper." (IV. Vibration Damping Capacity). Trans. Am. Soc. Metals, vol. 29, 1941, pp. 402–414.

4 Dean, R. S., Anderson, C. T., and Jacobs, J. H. "The Alloys of Manganese and Copper, Microstructure of the Alloys." Presented at meeting of American Society for Metals. Not yet published.

5 Dean, R. S., and Anderson, C. T. "The Alloys of Manganese Copper and Nickel." (I. Hardening in the Pseudo Binary System CuMnNi.) Submitted to American Society for Metals.

HARDNESS OF HEAT TREATED ALLOYS.

Mn, %	Ni, %	Cu, %	Rockwell E Hardness. 12 Hours, 350°.	3 Hours, 400°.	3 Hours, 450°.	12 Hours, 500°.	4 Hours, 550°.
20	20	60	23	33	40	32	—21
20	12½	67½	12	14	23	—7	—29
17	17	66	17	20	30	17	—24
15	17½	67½	13	14	18	3	—30
15	15	70	10	13	19	—6	—39
12½	12½	75	2	3	3	—20	—38

The coefficient of thermal expansion of the manganese-copper-nickel alloys is of special interest and considerable practical importance. It has already been stated that alloys of manganese and nickel containing approximately 70% manganese had an abnormally high temperature coefficient. The addition of copper to such alloys increases considerably this coefficient of expansion, and it reaches a maximum at about 72% manganese, 18% copper, and 10% nickel.

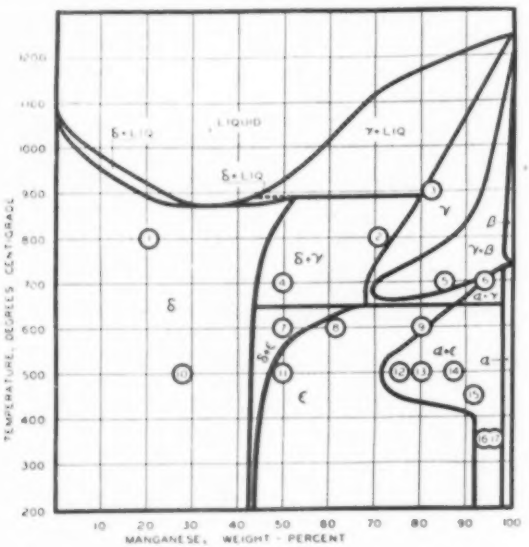


Fig. 4.—Manganese copper constitution diagram.

One of the principal fields of use for alloys of manganese, nickel and copper is in the preparation of standard electrical resistances. Previous investigations of this system have not covered alloys high in manganese because of their lack of ductility; however, if electrolytic manganese is employed, virtually all alloys of copper, nickel and manganese can be obtained in ductile form.

Alloys of Aluminium and Electrolytic Manganese

The behaviour of both electrolytic and, presumably, silico-thermic manganese, when heated with relatively pure Hoopes-process aluminium at 900° C. in clay crucibles, has been compared. The analysis of the silico-thermic manganese is given as 0·805% Si, 0·036% Al, 0·140% C, 2·04% Fe, 0·028% N, 0·011% S, 0·035% Cu, 0·009% Ni, 0·007% Co. Both kinds of manganese were sized through 10- or 28-mesh; 10% of manganese and 90% of aluminium were used in each test.

The initial rate of solution for the electrolytic manganese was a little higher. After 10 mins., with no stirring except on sampling, the electrolytic manganese had formed an alloy containing 2·25% manganese, whereas the silico-thermic manganese had dissolved only to the extent of forming an alloy containing 1·5% manganese. At the end of 20 mins., however, the composition of the two alloys was virtually the same. After 1 hour, both alloys contained 3% manganese. The alloys were cast in a chill mould. The surface appearance and fracture of the castings were quite different.

The alloy made from electrolytic manganese was very ductile and was readily rolled into foil without intermediate annealing. The full cold-rolled alloy had a hardness on the Rockwell B scale of R_b 23. The alloy made from silico-thermic manganese cracked badly after a reduction of 50%, and showed a hardness with this small amount of cold work of R_b 20. With 50% reduction the hardness of the electrolytic manganese alloys was R_b 4.

To check this remarkable difference in properties, two more alloys were made in the same way except that the melt was stirred. This second series of alloys contained 6% manganese. The alloy from silico-thermic manganese was brittle and worthless. The alloy from electrolytic manganese was ductile and could be rolled into thin sheets with light reductions. A third series of alloys contained 8% manganese. Again, the alloy from silico-thermic manganese was worthless. The 8% alloy with electrolytic manganese was ductile enough for reduction by very light passes and made a dense tough casting with a hardness of R_b 8. Apparently, $MnAl_6$ is the principal manganese constituent of both alloys, but the amount, shape, and size of the crystals are quite different. A phenomenon similar to modification of the aluminium-silicon alloys seems to have occurred.

Canadian Bentonitic Clays as Bonding Materials for Synthetic Moulding Sands

AN interesting report on the testing of five samples of bentonitic clays as bonding material for synthetic moulding sand mixtures, carried out in 1941 in the Milling Laboratory, Division of Industrial Minerals, Mines and Geology Branch, Department of Mines and Resources, is published in the current issue of the *Bulletin of the Imperial Institute* by kind permission of the Canadian Government Trade Commissioner in London.

The five samples of bentonitic clays were submitted by Pembina Mountain Clays, Ltd., of these three, designated A, B and E, were said to be products of the above Company from a deposit in Manitoba. The E clay, known as their yellow band, is a bentonite; the B clay, known as their black band, is a plastic type; the A clay is a mixture of E and B. The remaining clays, C and D, were of the bentonite type.

It was desired to determine the relative values of the various clays as bonding ingredients for synthetic moulding sands. With one exception all the tests made were adopted either as standard or tentative standard by the American Foundrymen's Association, as given in their publication, "Testing and Grading Foundry Sands and Clays." The tests pertain to permeability, compressive strength, and exact moisture content of all the synthetic moulding sand mixtures made from various combinations of the five clays as bonding material with two sands as base material at different moisture contents. In all, over sixty tempered mixtures were tested. The remaining test, which is the exception mentioned above, was that of determining the pyrometric cone equivalents of the five clays so as to secure an indication of the relative values of their refractoriness. The results are given in a number of tables, from a study of which the following deductions are made.

All the true bentonitic clays, E, C and D, would provide excellent bond for synthetic moulding sand mixtures. The domestic clays E and C are superior to the imported clay D in all respects for permeability, compressive strength and refractoriness. As for the domestic clays E and C, they are quite similar in their bonding qualities, but the preference is given to the E Pembina clay. Out of 36 determinations for permeability and compressive strength, only three determinations for permeability slightly favoured the C Alberta clay. For durability they should be equal.

It is to be noted that had base sands of different textures been supplied for these tests, the determinations for permeability and compressive strength would not have been the same, but the same general trend of results obtained would be as enumerated in this summary.

Impact Strength of Copper

A study has been made of the impact strength of deoxidised arsenical and non-arsenical, and tough-pitch arsenical and non-arsenical coppers, in the form of extruded rod and rolled plate. In addition, the effect of grain-size and temperature on impact strength have been investigated. The results of tests on all four coppers are given.

THE capacity of metals to withstand shock is usually measured by some kind of impact test, of which there are several in use ; in Britain the Izod impact test is usually employed. The impact test has been in general use for many years in testing ferrous materials and the impact value, at least in some applications, is regarded as one of the most informative test results. With few exceptions, however, this form of test has not been used to any great extent in testing non-ferrous materials, although there are indications of more interest being taken in, and more importance attached to, the shock resistance of non-ferrous metals and alloys. So far as copper is concerned, there is very little information available regarding Izod impact values, and the object of the work described by Dr. M. Cook and E. C. Larke* was to investigate the impact strength of deoxidised and tough-pitch arsenical and non-arsenical coppers, to obtain typical values for these different types of copper, and to ascertain the effects of cold-working, temperature, and grain-size on impact strength.

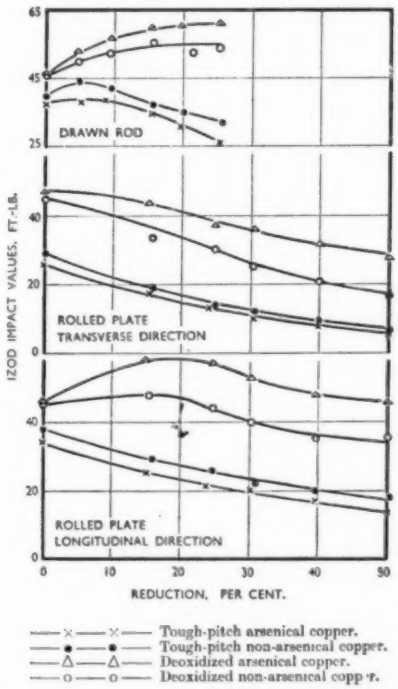


Fig. 1.—Izod impact values of deoxidised arsenical and non-arsenical and tough-pitch arsenical and non-arsenical coppers in the forms of rolled plate and drawn rod.

All the impact tests were carried out on an Avery Izod impact testing machine, with a capacity of 120 ft.-lb., and standard B.S.I. test-pieces were used. These were 10 × 10 mm. in cross-section, with a 45° notch, 2 mm. deep, and having a root radius of 0·25 mm. In most of the tests the specimens were not completely fractured. Tensile tests on both rods and plates were carried out on round test-pieces, 0·272 in. in diameter, with screwed ends.

Tests on Hot-rolled Plate

Samples of hot-rolled plate of four varieties, including commercial deoxidised and tough-pitch arsenical and non-arsenical copper, were collected over a period of several months from normal commercial production, and Izod tests were carried out on specimens cut in the direction of final rolling. The results of these tests are tabulated, and it is shown that no marked difference in impact values exists between tough-pitch arsenical and tough-pitch non-arsenical copper, nor is there any appreciable difference in the values for deoxidised arsenical and deoxidised non-arsenical copper. Thus, the presence or absence of arsenic in the amounts usually added to copper has no effect on the impact strength. On the other hand, both varieties of deoxidised copper show appreciably higher impact values than the two corresponding varieties of tough-pitch copper.

Tests on Cold-rolled Plate

Cakes of each of the four varieties of copper were hot-rolled to a thickness of $1\frac{3}{4}$ in. At this stage portions of each were cold-rolled in three passes to 1 in. thickness, and then all were annealed together. Samples for test were removed from each of the four coppers in this condition and then the remainder was subjected to cold-rolling reductions of 15, 25, 30, 40 and 50% in thickness, suitable samples for hardness, tensile and Izod tests being taken at each stage. Specimens for tensile and Izod tests were cut in directions transverse and parallel to the rolling directions, and the results obtained, together with those of the hardness tests, are tabulated. Both varieties and deoxidised copper again show higher impact values than the corresponding varieties of tough-pitch copper. To illustrate the effect of cold work more clearly, the Izod values have been reproduced in Fig. 1.

With progressively increasing amounts of cold work the tensile strength of copper becomes slightly greater in the transverse direction than in the rolling direction, whereas the impact strength in the former direction becomes less than that in the latter. It is of interest to note that, in the annealed condition, whereas the tough-pitch varieties show the same order of difference between the two directions as they do after rolling, the Izod values of the two deoxidised varieties in the annealed condition are substantially the same in both directions.

Tests on Extruded and Drawn Rod

Rods of the four varieties of copper were obtained in the extruded condition with a diameter of $1\frac{1}{8}$ in. In order to obtain all four in a condition as uniform as possible, the rods were drawn down to a diameter of 0·860 in., at which stage they were all annealed together. Thereafter they were cold-drawn, and after each draw appropriate lengths were reserved for Izod, tensile, and hardness tests. These were carried out on material as annealed and after reductions in cross-sectional area of 5, 10, 15, 20 and 25%. The results of these tests are tabulated, and the Izod values are included in Fig. 1. They show, like the results on hot- and cold-rolled plates, that both the deoxidised arsenical and non-arsenical coppers have appreciably higher impact values than the two corresponding varieties of tough-pitch copper, and that the effect of arsenic on the impact strength of tough-pitch or deoxidised copper is not very marked. The effect of cold working, in the form of drawing, on the rods is to raise the Izod values of the deoxidised coppers. The reduction in drawing, however, was limited to 25%, and it seems possible that with higher reductions the curves may take a form similar to those of the Izod test values on cold-rolled plate, in the case of which, with the deoxidised coppers, the values increased with reductions up to about 20 or 25%, and thereafter decreased. With the tough-pitch coppers, the Izod values on rod do not sensibly alter with reductions up to about 10% in cross-sectional area, and thereafter they steadily decrease up to the highest reduction, 25%, to which the material was subjected.

* *Jour. Inst. Metals* (Jan., 1942), 68, pp. 1–14.

Effect of Temperature.

On specimens cut parallel to the direction of rolling, from the same four plates as were used to determine the effect of cold rolling, Izod tests were carried out at temperatures ranging from normal up to 800° C., and the results obtained are shown graphically in Fig. 2. The specimens were superheated to allow for the temperature drop in the brief interval of time elapsing between the withdrawal of the test-pieces from the electrically heated furnace adjacent to the Izod machine, and the actual impact, the amount of superheat having been previously determined for each test temperature by actual measurements. Fig. 2 shows that the deoxidised and tough-pitch varieties of both arsenical and non-arsenical copper maintain their impact strength fairly well up to temperatures of the order of 350° to 400° C. The most marked decrease is shown by the tough-pitch non-arsenical copper, and this copper also shows the most pronounced dip in the region of 250°–300° C., which seems to characterise the impact strength-temperature curves of all four coppers. Above 400° C. all the curves fall steadily, those for the deoxidised coppers at the greatest rate, until in the region of 700°–800° C. the values for the four are not sensibly different.

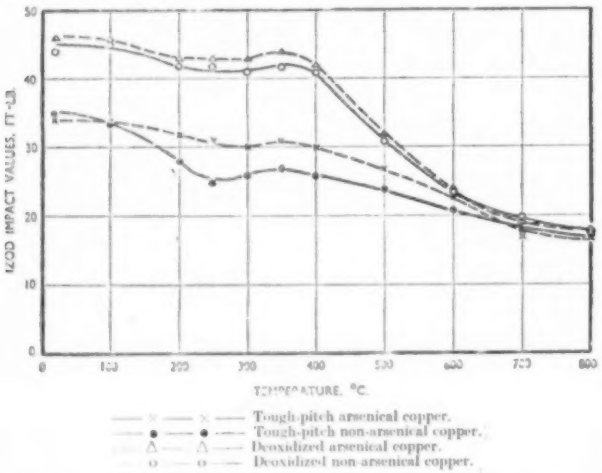


Fig. 2.—The effect of temperature on the impact strength of cold-rolled deoxidised arsenical and non-arsenical, and tough-pitch arsenical and non-arsenical coppers.

Effect of Grain Size

It has been previously shown[1] that the effect of grain size on the impact strength of deoxidised and tough-pitch arsenical copper is only very slight and that the difference between materials with a uniform grain-size of 0·05 mm. and materials with a coarsely crystalline structure in which the grain-size varied from 0·5 mm. to 2 mm., was only of the order of 2–4 ft.-lb. Specimens from the four cold-rolled plates were annealed at different temperatures up to 950° C. to provide a series of varying grain-sizes. In the material so prepared the grain-size ranged from 0·025 mm. up to about 1 mm., according to the annealing conditions and to the composition of the copper. The results on all four coppers confirmed the findings referred to above on arsenical coppers—namely, that the impact strength does not vary sensibly with the grain-size.

Characteristics of Deoxidised and Tough-Pitch Arsenical and Non-arsenical Coppers

In the course of this work, both representative commercial samples, taken over a period of time, and material especially prepared so that, apart from the variation deliberately made in respect of arsenic additions and deoxidation, they were strictly comparable in respect of composition and in details of manufacture, have been used. The results indicate that deoxidised arsenical and non-arsenical coppers have appreciably higher impact strengths than the corresponding varieties of tough-pitch copper, and that the presence of arsenic in either tough-pitch or deoxidised copper does not markedly affect the impact strength.

Arsenical copper has been extensively used for many years in a variety of forms for several purposes. In the quantity in which it is normally present, that is, 0·3–0·5%, which is wholly in solid solution in the copper, arsenic has no very marked influence on the mechanical properties of the metal, as the results of this investigation show, although it tends to increase the strength a little. It is shown that arsenic raises slightly the softening or recrystallisation temperature. In some applications at least arsenical coppers appear to be more resistant to oxidation at moderately elevated temperatures than the corresponding non-arsenical coppers. It is claimed that the presence of arsenic also has the effect of improving the hot- and cold-working qualities of copper, and whilst little evidence may have been adduced in support of this, it is known that any merits or peculiarities which materials may show in certain fabricating processes are not always revealed or indicated by the usual type of physical or mechanical test.

Deoxidised copper has been developed commercially only in recent years, although it is now very extensively used. The softening temperature of deoxidised copper is higher than that of the corresponding tough-pitch copper, and, on annealing, the rate of grain growth in deoxidised coppers is appreciably greater than it is in tough-pitch coppers. Deoxidised coppers, either arsenical or non-arsenical, are slightly stronger and more ductile than the corresponding tough-pitch coppers. In this country the common practice is to effect deoxidation by the addition of phosphorus, and this type of copper, by virtue of the absence of oxygen and the presence of phosphorus, is more suitable for welding than is tough-pitch copper. It is this combination of excellent welding characteristics with improved mechanical properties that is responsible for the increased use of deoxidised copper for many industrial purposes.

[1] M. Cook. *Journ. Inst. Locomotive Eng.* 1938, **28**, p. 609.

Institute of Metals Medal

THE Platinum Medal of the Institute of Metals for 1942 has been awarded to Mr. W. Murray Morrison, vice-chairman and managing director of the British Aluminium Co., Ltd., in recognition of his outstanding services to the non-ferrous metals industries. Mr. Morrison is an original member and Fellow of the Institute of Metals, on the Council of which he served for 16 years—in the last two as vice-president.

Mr. Morrison has been concerned with the development of the aluminium industry since its inception in this country over forty years ago: it is largely due to his energy and foresight that the hydro-power resources of the Highlands of Scotland have been developed to their present extent. It is expected that this medal will be presented on the occasion of the Annual General Meeting of the Institute, to be held in London in March.

X-Ray Analysis in Industry

THE Institute of Physics is arranging a conference on "X-ray Analysis in Industry," to be held in Cambridge, on April 10 and 11 next. The purpose of the conference is to promote the interchange of knowledge and experience between those employing X-ray analysis (diffraction methods) in their work in different fields and to arrange for further collaboration between physicists, engineers, chemists and others towards the solution of problems by its methods.

During the conference, the president, Professor Sir Lawrence Bragg, will lecture on "The History and Development of X-ray Analysis." Further particulars can be obtained from the Secretary of the Institute of Physics, temporary address at the University, Reading, Berks., to whom application for accommodation in Cambridge should be made without delay.

Resistance to Cavitation Erosion

The mechanism of cavitation erosion is discussed, and it is concluded that the attack is primarily of a mechanical nature. Corrosion plays a part similar to that played in lowering the fatigue limit of a metal in a corrosive medium. The vibratory cavitation erosion testing apparatus is described and the results of tests on a number of alloys suitable for propellers and pump impellers are given.

CAVITATION erosion is a phenomenon only too familiar to shipbuilders and propeller manufacturers, leading as it frequently does to premature failure of both propellers and of rotary pump impellers. The fact that it is an even more serious trouble to manufacturers and users of hydro-electric equipment may serve to explain why the problem has been investigated fairly persistently by them, while largely neglected by the shipbuilding interests, although the first steps towards the understanding of erosion were made as a result of trouble experienced with ship propellers. It was as a result of experience of the pitting of the *Mauretania's* propellers in 1912 that the view was first expressed that the erosive effect of cavitation was responsible for this type of attack. Subsequent investigation led to conclusions which, while they clearly pointed the way, did not result in finding a greatly superior alloy. This apparent sluggishness is undoubtedly due to the difficulty of conducting full-scale tests on a variety of materials and the lack of any laboratory test which could be relied upon to reproduce service conditions. The purpose of a recent paper by Dr. R. Beeching* is to bring to the particular notice of shipbuilders the vibratory method† of testing the resistance of materials to cavitation which has already been employed in America in connection with the testing of materials for water turbines.

The Mechanism of Cavitation Erosion

There is still some divergence of opinion as to the reason for the pitting of marine propellers, pump impellers, turbine runners and similar hydraulic equipment by the process commonly referred to as cavitation erosion, the difference in views being such as to call into question the suitability of this naming, since one school of thought is inclined to the opinion that the process is essentially one of corrosion and not, as is more commonly supposed, a mechanical process of erosion. From the literature on the subject published since the report of the Propeller Sub-Committee one gathers the impression that investigators are unanimous in deciding that the process is primarily mechanical, but the fact that all authors are at some trouble to express this opinion and to produce supporting evidence of a fairly definite, but not necessarily conclusive nature, is an indication of their consciousness of the prevalence of the opposite view, which is quite widely held among those whose experience of cavitation erosion has been gained from observations under service conditions and not under conditions of careful control.

To reach a conclusion as to the mechanism whereby pitting occurs, a review of the evidence in favour of the theory that it is due to erosion is helpful. This evidence starts with the work of the 1915 Propeller Sub-Committee‡ Their conclusions may be summarised as follows :—

The conclusions arrived at are that the corrosion of propellers is very slight, but that erosion is serious and is caused by the hammer action of the water on the propeller blades produced by cavities closing up on the surface of the blade. This action may be caused either by cavitation of the propeller itself, occurring more generally when the propeller is in a varying wake, or by the cavities and vortices formed by the action of other propellers ahead of it, and the erosive action is generally aggravated upon a propeller which works in the wake of another. The water hammer effect is also likely to be produced when the cavities are formed in the water by the form of the stern frame, shaft bossing or A-brackets, or when the lines are very full or such as to cause an eddying wake.

From the calculations it appears that the pressure of the water hammer is independent of the size of the cavity, depending only on the ratio of its contraction, so that the cavities of the erosion may be large or small. Cavitation in itself will only produce erosion when accompanied by conditions which cause the cavities to collapse in such a way and in such a position that the energy of collapse is concentrated on a small portion of the propeller surface.

The most important of these conclusions is stated in the first sentence, and worded thus as a mere statement of fact it hardly does justice to the work of the Committee, which produced quite substantial evidence in support of the view expressed. Among the propellers examined, some were found to have been distorted in service by the action of water hammer, being convex on the back where the pitting had occurred and not, as might be expected, on the face, as would have been the case had bending been caused by the main thrust. It was concluded that this bending was due to the expansion of the surface layers by local hammering. Perhaps their most valuable contribution was a demonstration that the collapse of cavities would cause stresses as high as 60 tons per sq. in. or even more.

Since the conclusions discussed above were published, several investigators have concerned themselves with the measurement of the intensity of the hammer action occurring as a result of cavitation, and while most of them have been convinced that it is such hammering action which causes pitting, they have in several instances arrived at the conclusion that the pressures produced by the impacts are not sufficient to cause plastic deformation of most metals. The results of these investigations have been summarised in a paper by P. Haller,§ who comes to the same conclusions and is inclined to think that an explanation of the deformation which is actually seen to occur on microscopic examination of some materials will only be found by more advanced considerations, taking into account the structure of the actual crystal lattice.

It is considered that this view is wrong, and that the evidence produced to show that the pressures due to the collapse of cavities are too small to produce plastic deformation or fatigue cracking is open to serious criticism and is not nearly so straightforward as the original experiments demonstrating that stresses sufficient to cause fatigue of the hardest materials may occur. In view of the number of experiments that have been carried out and from which the same deduction has been made, this appears rather a sweeping criticism and needs justification.

Some previous investigators, having concluded that cavitation erosion is a mechanical form of attack, have attempted to correlate resistance to erosion and fatigue strength or, in some cases, tensile strength, and their failure to do this has sometimes been used as the basis of argument against the theory ; no correlation, however, is to be expected for alloys in general. The stresses resulting from the collapse of cavities will exceed the fatigue limits of most alloys, so that erosion will depend upon the number of repetitions of a large stress which a material will endure, rather than upon whether the smallest stress which will

* " Resistance to Cavitation Erosion." Inst. Eng. and Shipbuilders in Scotland. (Preprint, Feb., 1942.)

† Schumb, Peters and Milligan. *Metals and Alloys*, May, 1937, p. 126. Kerr. *Trans. Am. Soc. Mech. Eng.*, 1937, **59**, p. 373.

‡ *Trans. Inst. Naval Architects*, 1919, **61**, p. 223.

§ *Schweizer Archiv. fur Angewandte Wissenschaft und Technik*, March, 1940. p. 61

ultimately cause failure is high or low. Further, there is the disturbing influence of corrosion, but again, because the stresses far exceed the corrosion fatigue limits of most alloys, no direct correlation is to be expected, more especially since the intensity of the stresses and the resulting rapidity of removal of the surface layers may prevent corrosion from playing the same part as it would in the case of a normal rotating beam type of test, where pitting, with resulting stress concentration, is of such importance.

Should it be desired to correlate resistance to erosion and fatigue limits, the obvious way would be to make tests to determine the minimum intensity of the cavitation blows necessary to make erosion begin, and probably this could best be done by means of the rotating disc type of test. However, it seems best to regard cavitation erosion as a distinct phenomenon and not endeavour to explain the effect completely in terms of either normal or corrosion fatigue.

The conclusions with regard to the mechanism of attack may be summarised as follows :—

1. Cavitation erosion results primarily from the repeated deformation of the surface layers of a metal exposed to the attack, as a result of the high sheer stresses produced in the metal by the pressure impacts caused by the collapse of cavities in the fluid. These stresses will vary in intensity as a result of many factors, but will, in severe cases, reach values exceeding the fatigue limits of the most resistant materials.

2. As a result of the repeated application of stresses exceeding the " pitting limit " of McAdam,‖ the corrosion of the surface may be accelerated, and has certainly been shown to be accelerated in some cases. In turn, this corrosion, which need only produce very small pits to cause stress concentration in such highly localised stress fields as those due to the collapse of cavities, will accelerate the mechanical disruption of the surface.

3. For an alloy to have a high resistance to cavitation erosion, it is necessary that it should have a high resistance to repeated stressing above the fatigue limit and also high resistance to corrosion even when repeatedly stressed.

If these conclusions are assumed correct, it permits judgment as to the suitability of any laboratory test as a basis for selecting materials to be used under service conditions.

The Vibratory Method of Testing the Resistance of Alloys to Cavitation Erosion

The vibratory method of cavitation erosion testing has been used by Schumb, Peters and Milligan, and also by Kerr. A specimen of the alloy to be tested is vibrated at a high frequency, in a direction perpendicular to the face to be eroded, while immersed in a bath of the test liquid. Although the amplitude of vibration is relatively small, the accelerations suffered by the specimen are high. As a result of the inertia of the liquid a low-pressure zone is established over the centre of the specimen face on the upward stroke and, in this zone, cavities are formed by boiling. On the downward stroke, the inertia of the liquid causes a zone of high pressure beneath the surface of the specimen. At some stage of the change-over from low to high pressures, the cavities collapse, in much the same way as cavities formed on the suction side of a propeller or turbine runner will collapse as they are carried into a zone of higher pressure.

For the purpose of the work described by Dr. Beeching, the apparatus used was similar to that employed by the investigators mentioned above, but differed in some respects. The specimen, in the form of a short cylindrical plug with a circular end cap having a concave spherical face, was machined so that the cylindrical portion was a tight press fit in the end of a hard-drawn nickel tube of approximately $\frac{5}{8}$ in. outside diameter and $\frac{1}{16}$ in. wall thickness. The tube, which was about $10\frac{1}{2}$ in. in length, was mounted vertically and supported by a rubber bush at its centre. By virtue of the magneto-strictive effect in nickel, the tube was made to vibrate longitudinally, with a node at the centre, by applying to it a rapidly alternating magnetic field tuned to the natural frequency of the tube (9,000 cycles per sec.). This magnetic field was produced by means of a high-frequency alternating current supplied to a coil concentric with the tube by means of a valve oscillator with an output of 350 watts.

Before this apparatus was used for surveying the resistance to erosion of alloys at present used for hydraulic equipment or as a guide in developing new alloys, the author considered it advisable to make some preliminary tests to determine the test conditions which should be adopted as standard. Since these preliminary tests were regarded as supplementary to those already made by Schumb, Peters and Milligan, and by Kerr, a brief summary of their work is given below.

Schumb, Peters and Milligan made tests to determine the relative rates of erosion of a few alloys in distilled water, and then went on to study the effects of various test liquids, namely, fresh water, 20% sodium chloride solution, methyl alcohol, and carbon tetrachloride at various temperatures. The results of greatest interest for the present purpose are those obtained with fresh water and salt solution. It was found that at all temperatures between 0° and 70° C. the loss of weight in salt solution exceeded that in fresh water, for the particular alloys tested. Further, it was found that the erosion in both liquids increased with increasing temperature up to about 50° C. and then began to decrease again. The authors inclined to the view that the difference in the solubility of air in the two liquids accounted for the different rates of erosion and that the increase of erosion with increasing temperature was due to a decrease in the amount of air dissolved. The fall of the erosion rate at higher temperatures they consider to be due to the increased vapour pressure of the test liquid.

Apart from any question as to the underlying reasons for the effect observed, the work of these authors shows the importance of suitable choice of test liquid and of temperature in fixing conditions of test to simulate average service conditions. In addition to this work, which had already been carried out, it was considered desirable to investigate the effect of varying the intensity of erosion with a view to determining whether this factor caused a change in the relative rates of loss of weight of a number of alloys. For this purpose three high tensile brasses were selected, two of which were expected to differ little in their resistance to erosion and the third of which was expected to be decidedly more resistant. These alloys were designated X, Y and Z respectively.

The intensity of vibration was varied in a variety of ways—namely, by changing the amplitude of vibration, by using specimens with flat and concave faces, since it is obvious from the manner in which cavitation is produced on the specimen face that a concave specimen will increase the effect, and by taking advantage of the increased rate of erosion found by Schumb, Peters and Milligan to result from changing from distilled water to sea-water and from increase of temperature. Accordingly, the three materials were examined under the following conditions :—

1. Flat specimen in sea-water at 19° C. with 350 watts H.F. output.
2. Concave specimen in sea-water at 19° C. with 350 watts H.F. output.
3. Concave specimen in fresh water at 19° C. with 350 watts H.F. output.
4. Concave specimen in sea-water at 19° C. with 275 watts H.F. output.
5. Concave specimens in sea-water at 40° C. with 350 watts H.F. output.

Each specimen was eroded for three periods of 30 mins. and weighed before and after each period. The losses in weight suffered by the three materials are shown in Table I.

As was found by previous investigators, the loss of weight during the initial period of erosion is less than that during

‖ Proc. Am. Inst. Min. and Met. Eng., Inst. Met. Divn., 1928, p. 571.

subsequent periods, so that for the purpose of comparing alloys the total weight lost during the last two 30-min. periods was adopted as a criterion. The ratios of the weights lost by the three alloys during the period are shown in Table II.

TABLE I.
LOSSES OF WEIGHT IN PRELIMINARY TESTS.

Conditions of Test.	Loss of Weight.					
	Specimen X.		Specimen Y.		Specimen Z.	
	First 30 mins.	Last 60 mins.	First 30 mins.	Last 60 mins.	First 30 mins.	Last 60 mins.
	Mg.	Mg.	Mg.	Mg.	Mg.	Mg.
Flat specimen in sea water at 19° C. Intense vibration	1·3	11·1	4·4	19·1	0·6	3·8
Curved specimen in sea water at 19° C. Intense vibration	6·7	18·8	8·9	21·1	2·7	7·8
Curved specimen in fresh water at 19° C. Intense vibration	4·5	16·2	5·0	16·7	1·9	7·6
Curved specimen in sea-water at 19° C. Weak vibration	4·1	13·2	3·2	17·3	1·0	3·6
Curved specimen in sea-water at 40° C. Intense vibration	6·9	23·7	11·5	27·6	2·1	8·5

TABLE II.
RATIOS OF WEIGHTS LOST.

Conditions of Test.	Loss by Alloy X / Loss by Alloy Z	Loss by Alloy Y / Loss by Alloy Z	Loss by Alloy Y / Loss by Alloy X
1	2·9	5·2	1·8
2	2·4	2·7	1·1
3	2·1	2·2	1·1
4	3·7	4·8	1·3
5	2·8	3·2	1·2

These preliminary experiments showed that it is important to test alloys for marine propellers in sea-water, and, further, that both temperature and the intensity of the conditions producing cavitation will influence the relative rates of erosion of a series of alloys, although they will not necessarily cause any reversals in their order of merit. It appears that the adoption of very mild cavitation conditions tend to increase the differences between good and bad alloys, and this is not surprising when it is considered that there must be limiting conditions where the stresses set up are intense enough to disrupt poor materials, but will be below the corrosion fatigue limits of resistant alloys.

On the basis of these considerations, Dr. Beeching adopted the following conditions of test as standard for the comparison of alloys to be used in sea-water. Specimens with a concave face, turned to 1-in. radius, were employed, and the surface was lapped truly spherical with successively finer grades of carborundum and finished with flour emery. The tests were made for three 30-min. periods in a bath of sea-water at 19° C., with an intensity of vibration association with a high-frequency output of 350 watts. The rate of erosion of a typical sample of Admiralty manganese bronze under these conditions is equivalent to approximately 1 lb. per sq. ft. per day, which represents a rate of erosion of the same order as that which occurs in severe cases in practice.

Comparative Tests upon Alloys

The alloys selected for test may be divided roughly into three classes by virtue of their casting and mechanical properties—namely, those suitable for large propellers, those suitable for high-speed propellers for fast motor-launches, and those used for pump impellers. Most of the specimens tested were commercially produced samples representative of normal production, but some were made specially for the purpose of the present tests, and in this case they were cast under conditions suitably representative of the class to which they belong. The alloys were tested in duplicate, except in the case of the impeller alloys, one test was made in distilled water instead of in sea-water. With a few exceptions, the composition, tensile strength, proof stress, hardness and elongation of the alloys tested are shown in Table III, together with the results of the vibratory cavitation tests on these alloys.

In order to express the results in a manner more nearly independent of the conditions of test, a figure of merit was calculated for each alloy by taking the reciprocal of the ratio of its loss of weight during the final 60 mins. erosion to the corresponding loss of weight of the Admiralty propeller bronze sample. The figures of merit calculated in this way, both for fresh and sea-water, are tabulated in the last two columns of Table III.

TABLE III.—RESULTS FROM ALLOYS TESTED.

Sample No.	Type of Alloy.	Condition.	Brinell Hardness.	Proof Stress 0·1% Offset.	Maximum Stress.	Elongation.	Weight Loss by Erosion.				Figure of Merit Relative to Adm. Propeller Bronze.	
							Sea Water.		Distilled Water.			
							First 30 mins.	Next 60 mins.	First 30 mins.	Next 60 mins.	Sea Water.	Distilled Water.
	Cast High Tensile Brasses			Tons per Sq. In.	Tons per Sq. In.	%	Mg.	Mg.	Mg.	Mg.		
1	Admiralty propeller bronze	Sand cast	156	17·6	35·2	27	5·9	18·9	4·6	16·2	1·0	1·0
2	Special high tensile brass (A)	,, ,,	156	16·5	38·0	36	3·6	13·9	—	—	1·35	—
3	,, ,, ,, ,, (B)	,, ,,	145	17·5 Y.P.	38·5	18	2·5	11·2	—	—	1·7	—
4	,, ,, ,, ,, (C)	,, ,,	101	17·7 Y.P.	39·6	28	3·0	9·5	—	—	2·0	—
5	,, ,, ,, ,, (D)	,, ,,	175	—	40·9	20	2·6	8·9	—	—	2·1	—
6	,, ,, ,, ,, (E)	,, ,,	175	—	40·0	15	2·7	8·8	—	—	2·15	—
	Cast Aluminium Bronzes (Ni-Fe-Al)											
7	DTD. 197	,, ,,	169	17·0 (0·5%)	40·1	24	1·45	4·75	—	—	4·0	—
8	Aluminium bronze (A)	,, ,,	154	18·0 (0·5%)	38·5	27	0·90	4·55	—	—	4·15	—
9	,, ,, (B)	,, ,,	128	14·0 (0·5%)	36·0	27	1·45	6·25	—	—	3·0	—
	Cast Nickel-Copper Alloys											
10	Monel	,, ,,	139	16·6 (0·5%)	37·2	35	3·7	13·1	3·2	13·6	1·4	1·2
11	Special nickel-copper alloy (A)	,, ,,	226	31·6 (0·5%)	49·0	12	2·2	8·65	—	—	2·2	—
12	,, ,, ,, ,, (B)	,, ,,	215	34·0 (0·5%)	52·4	34	1·7	8·15	—	—	2·3	—
13	,, ,, ,, ,, (C)	,, ,,	253	36·6 (0·5%)	59·6	15	1·15	5·8	—	—	3·25	—
	Cast Gunmetals and Bronzes											
14	Admiralty gunmetal	,, ,,	84	8·8	16·6	13	1·9	18·9	4·9	14·3	1·0	1·15
15	Gunmetal (B.S.S. 900-1/1940)	,, ,,	72	5·1	16·6	25	2·0	22·1	6·2	22·6	0·85	0·71
16	Gunmetal (B.S.S. 897-8/1940)	,, ,,	62	6·4	13·2	19	10·8	25·0	12·8	24·3	0·76	0·67
17	Low nickel bronze (A)	,, ,,	99	10·8	21·6	18	6·5	23·8	5·6	25·8	0·79	0·63
18	,, ,, ,, (B)	,, ,,	93	21·8 (0·5%)	21·8	42	11·6	27·6	11·9	24·6	0·68	0·66
19	,, ,, ,, (B) heat-treated	5 hours 700° C. W.Q. 5 ,, 350° C. W.Q.	208	30·6 (0·5%)	38·0	3	9·3	20·3	2·2	16·0	0·93	1·1
20	Admiralty phosphor bronze	Sand cast	72	6·7	15·2	13	7·2	19·4	6·1	20·5	0·97	0·80
	Cast Miscellaneous Non-Ferrous Alloys											
21	α brass with additions (A)	,, ,,	55	5·2 (0·5%)	15·0	42	8·8	20·1	—	—	0·94	—
22	,, ,, ,, ,, (B)	,, ,,	65	—	—	—	11·0	21·2	8·0	23·1	0·89	0·70
	Cast Irons											
23	Grey cast iron	,, ,,	214	—	13·2	—	25·9	46·9	19·1	30·2	0·4	0·54
24	Cylinder iron	,, ,,	244	—	20·6	—	15·6	33·3	3·3	12·7	0·57	1·25
25	Ni-Resist	,, ,,	179	—	14·6	—	4·4	15·5	2·3	5·8	1·20	2·80

In this table are included a number of commercial alloys supplied by various companies under proprietary names, and it was, therefore, thought best to avoid reference to compositions.

Discussion of Results

The results themselves show quite clearly the relative merits of the various alloys from the point of view of resistance to erosion under the conditions of test, and little is to be gained from discussing the behaviour of the different materials individually. It is, however, important to decide to what extent these results may be considered to indicate the behaviour of the alloys under service conditions. Our previous discussion of the mechanism whereby erosion occurs enables us to consider the factors which may cause differences between the attack upon a propeller in service and upon a specimen eroded by means of the vibratory test apparatus. Since sea-water was used for the tests, this eliminates the variables associated with the medium, and the test temperature of 19° C. approximates sufficiently closely to the average surface temperature of the ocean on sea routes to prevent the introduction of any great error from this cause. The only possible differences likely to affect the nature of the attack are, therefore, differences in the mode of formation and collapse of the cavities.

In all cases where cavitation occurs, the cavities are formed because the pressure in the liquid is reduced below the vapour pressure. In the case of the vibratory apparatus, the pressure is lowered as a result of the acceleration of the specimen away from the liquid, while in the case of propellers, the pressure is lowered generally on the back face and may, in parts, fall below the vapour pressure of sea-water. Also, local low pressure zones may be set up by eddies produced by irregularities in the blades. Whereas, in the case of the vibrated specimen, the cavities collapse because the low pressure is changed rapidly to a high pressure on the reverse stroke, in the case of a propeller the cavity will collapse either because some instability in the water flow causes a fluctuation of pressure on the blade or because the cavity is swept to a part of the blade where the pressure is higher. It will be appreciated that in essence the process is the same in each case, but the time of formation of the bubble and the rate of increase of pressure may be very different in the two cases. If cavities have a longer time in which to develop it is to be expected that they will be larger, and the larger the cavity the greater will be the area affected and the more deeply will the stresses penetrate the surface layers of any body in contact with which the cavity may collapse. If the pressure increases relatively slowly, the intensity of the impact will be small. As a result, therefore, the intensity of the blows may be either more or less intense, although it is possible, by a combination of circumstances that the weaker blows may affect a larger volume of material than intense ones. Therefore, while the rate of loss of material may be an indication of the intensity of attack in one sense, it is not necessarily an indication of either the frequency or intensity of the impacts suffered.

It can be said that the most probable difference between the cavitation attack on a vibratory test specimen and upon a propeller or impeller in service is in the intensity and that such variations of intensity as are likely to occur will not alter the order of merit of alloys. It is only necessary to remember that the more severe the conditions of service, the less pronounced do the differences in behaviour of various materials tend to become. In general, it is likely that service conditions will cause less severe erosion than the test conditions, so that the alloys shown to be good by the vibratory test will, in service, behave even better relative to alloys shown to be poor. For all practical purposes, therefore, the vibratory test may be relied upon as an indication of the relative resistance to cavitation erosion of various alloys otherwise suitable for propellers or pump impellers. However, it must be remembered that the description "otherwise suitable" means, among other things, that the alloys must be capable of withstanding normal corrosion in the medium in which the component must work. While it is true that alloys which best withstand erosion are generally also resistant to corrosion, it does not follow that the alloy most resistant to erosion will serve best under conditions where corrosion has much more prolonged opportunities to operate than cavitation. In selecting an alloy for any particular purpose, therefore, it is necessary to consider the conditions of service to decide whether corrosion or erosion is likely to be the more serious trouble, and to choose accordingly.

Screw Propeller Theory

PROPELLER theory in this country, so far as its application to marine screws is concerned, has been something of a Cinderella, a fact which is surprising when one considers the contributions made to the theory by research authorities of British nationality, notably Gluert,[1] Goldstein,[2] and Lock.[3] An exception to the neglect referred to is Perring's paper[4] applying the Glauert theory to a series of marine-type propellers, handicapped, however, by lack of suitable aerofoil data and now rendered partly obsolete by Goldstein's improved theory. To what extent, states Dr. J. L. Taylor,* the neglect has been due to the vested interests of dogmatic and somewhat dictatorial tank authorities must remain a matter for speculation; but if there has been a fear that the acceptance and widespread use of a satisfactory theory might lessen the scope and influence of the tanks, this has perhaps not been entirely without justification, although this term could hardly be applied to attempts to decry theory bolstered by quoting the defects of theories many years obsolete. Other exceptions to the neglect of theory are probably furnished by individual designers working without tank guidance, but one suspects that their methods would hardly bear investigation; in fact, this field over many years has been a particularly fruitful one for the empiricist, and even quite recently totally unsound theories have gained some currency and have reached practical application, with fairly disastrous results.

Dr. Taylor presents an account of propeller theory, collected from various sources and with certain additions, in a form suitable for immediate practical application. A short statement is first given of the simple nomenclature theory which is extended to include rotational as well as axial inflow. The Glauert theory for infinite number of blades also uses the momentum inflow values, but these are now calculated for each radius individually and applied to the known aerofoil characteristic to predict the performance or each blade section, and hence that of the screw as a whole. More nearly accurate are the inflows of the Goldstein vortex theory, which allows for finite number of blades and so-called "tip effect," and performances so predicted are in reasonable agreement with model and full-scale data. Finally, an approximate method of calculating the pressure distribution over a blade section is given for any arbitrary shape of section, and the application to cavitation condition discussed. In view of the reference made elsewhere in this issue to resistance to cavitation erosion, Dr. Taylor's consideration of the theory of cavitation is of interest and is reproduced from his paper in the following :—

1 Reports and Memoranda of the Aero. Res. Committee. "Aerofoil and Airscrew Theory."
2 Proc. of the Royal Soc. A vol. 123, 1929.
3 Reports and Memoranda, especially No. 1377.
4 "The Vortex Theory of Propellers and Its Application to the Wake Conditions Existing Behind a Ship." By W. G. A. Perring. *I.N.A.*, 1928.
* "Screw Propeller Theory." North East Coast Institution of Engineers and Shipbuilders. Feb., 1942. (Advance copy.)

Cavitation

The practical importance of being able to predict the pressure distribution over the blade surface lies mainly in

the application to the question of cavitation, and possibly as some authorities have suggested, "singing." The occurrence of a calculated suction peak reducing the local absolute pressure below the vapour tension of the water may be regarded as *prima facie* evidence of at least incipient breakdown, and so far as comparison has been possible, the agreement with practice in the case of fairly highly loaded propellers designed, however, to be free from cavitation, is good, and seems to show the validity of empirically arrived at limiting loadings appropriate to this class of screw. For still higher speeds and loadings, when cavitation has come to be regarded as more or less inevitable, though it may be kept within bounds, and the accepted design criteria in the shape of maximum permissible loadings and tip speeds are presumably intended to achieve this, the applicability of the theory is less evident, since once the flow has broken down the hydrodynamic characteristics of the section are unknown. A rough measure of severity of cavitation might be taken as the ratio of calculated suction (below the static pressure or immersion head) to the immersion head pressure; this ratio will be well over unity for all screws in the class described, affording some indirect confirmation of the theory; the extent of the suction peak may also have to be taken into account in judging the severity.

Theory suggests an explanation of erosion due to cavitation: a slight cavitation hollow or bubble on the surface of the blade gives an increased tendency towards suction (negative pressure), so that the hollow swells rapidly and exponentially until breakdown of flow occurs and the lift and circulation suddenly decrease, the fluid velocity becomes less, causing the pressure to rise so that the cavity collapses on to the blade; the unstable cycle described then repeats itself. If this description is even approximately true, it obviously becomes extremely difficult to specify the flow at each instant and to determine the forces on the blade. The observed fact that cavitation and erosion are not very closely linked, so that increased loading per unit area or even the adoption of a type of section which is inherently bad from the point of view of generating high local peak suction does not invariably increase erosion and may actually reduce or eliminate it, suggests that there is, in addition, an alternative possible steady flow regime, which presumably leaves part of the back of the blade permanently dry. There is definite evidence of such a regime at the very high forward and rotational speeds reached by racing motor-boats, when, in complete contrast with the normal operating condition, most of the lift is on the blade face; the flow can be calculated on certain assumptions, giving a face lift coefficient starting from zero at zero face incidence and having a slope one-quarter of the normal—i.e., $\pi/2$ per radian. The reduction is thrust and power absorption at a given slip is considerably less than that in lift at a given incidence, when inflow, calculated in the usual way, is taken into account, and agreement with full-scale data is reasonably good. The lower limit of this ultra-high-speed regime is, however, rather indefinite.

Bauxite Resources of the United States

Estimates of future needs of the United States defence programme have caused serious attention to be directed to the self-sufficiency of that country, both as to the supply of bauxite and the metallurgical capacity available to convert the ore to metallic aluminium. Resources of bauxite have been investigated in an effort to ascertain the tonnage of commercial and submarginal grades available in the United States, and this article summarises a comprehensive report of the results.

ALUMINIUM is the metallic base of the mineral alumina; chemically it is an element. Unlike many other minerals, it is never found native, though it is one of the most plentiful and widely distributed of all substances in combination with other materials. Only oxygen and silicon are more abundant in the world's crust. Despite the wide distribution of aluminium, the ore from which the metal is derived is, with few exceptions, the hydrate bauxite, itself containing a decomposition product of silicate. Vast deposits of this mineral, suitable for the extraction of the metal, have been located in every continent; in some countries, however, the demand for aluminium far exceeds the normal output of bauxite in those countries and have necessitated imports to make up deficiencies. With the whole structure of trade disturbed by a world war, many countries are giving great attention to domestic supplies and are exploring the possibilities of meeting increased requirements from their own mineral resources.

Production of metallic aluminium in the United States, for instance, was, until recently, ample to meet requirements, but estimates of pyramiding future needs of the defence programme has caused serious attention to be directed to the self-sufficiency of that country, both as to the supply of the raw material, bauxite, and the metallurgical capacity available to convert the ore to metallic aluminium. A recent investigation of United States resources of bauxite was undertaken by representatives of the Bureau of Mines and the Geological Survey, and J. R. Thoenen and E. F. Burchard have prepared a very comprehensive report* of the investigations.

The economic aspects of the bauxite resources of the United States will be appreciated from a recently published estimate of the requirements of primary aluminium. Towards the end of 1940 the Advisory Commission Council of National Defence estimated that by July of this year the annual national requirement for aluminium would be 412,500 short tons. In June of last year, however, the Office of Production Management issued a notice increasing the estimate to 800,000 short tons. For purposes of calculation, four short tons of bauxite (aluminium grade) are required to produce one short ton of metallic aluminium. Upon this basis, by July of this year, the United States will require 3,200,000 short tons (2,850,000 long tons) of bauxite annually. Reference to *Minerals Yearbook* for 1940 shows that domestic production of bauxite for metallic aluminium in that year was 214,194 long tons, and this was an increase of 33% over 1939 production. It will be seen, therefore, that an investigation into the subject of bauxite resources with a view to determining how near self-sufficiency can be approached is a stupendous task.

* United States Bureau of Mines Report of Investigations, 3598.

Grades of Ore Used

Bauxite is mined for a number of purposes, and each industry has set up certain specification requirements. In some instances these are quite rapid, while in others there is considerable tolerance. The common commercial grades, with their chemical requirements, are given in Table I.

COMMONLY ACCEPTED COMMERCIAL GRADES OF BAUXITE.

Grades.	Form in which Used.	Principal Chemical Constituents (Percentage Range).			
		Al_2O_3	SiO_2	Fe_2O_3	TiO_2
Aluminium	Dried	55–62	2– 7	3– 8	2–4
Chemical	„	54–62	2–11	1– 2·5	1–3
Abrasive	Calcined	80–86	4– 8	4– 9	2–5·4
Refractory	„	78–86	5– 8	2– 4	1–4
Cement	Largely undried	52–56	2– 3·5	2–15	2–4
Oil refining	Activated	75–80	4–10	5– 9	3–4

It will be noted that the tabulated specifications require that for metallic aluminium the bauxite must contain at least 55% alumina and not more than 7% silica, whereas the iron oxide may amount to as much as 8% and titanium oxide 4%. On the other hand, although the alumina content for purposes of the chemical industry must virtually equal that for the aluminium industry, there is more tolerance in respect to silica, but less in respect to iron oxide. Dried but uncalcined bauxite will contain 25 to 32% combined water, the average being about 30%. Calculated upon this basis, specifications for abrasive and refractory grades require 56 to 60% alumina, which is equivalent to the percentage required in the aluminium and chemical grades. The silica requirement, however, has become more stringent, not more than 6% being permitted. In these four grades the alumina content must be 54% or more, and the factor that determines selection for different uses seems to be the amount of silica or iron oxide present.

It is appreciated that bauxite containing less alumina and more silica can be used in the Bayer process, but material and operating costs would be increased substantially, as each pound of silica consumes more than a pound of soda ash, which is wasted, and every pound of silica carries away with it a pound of alumina. Furthermore, the cost of all subsequent treatment would be increased. In spite of this, it is understood that some bauxite containing as little as 50% alumina and as much as 8% silica is now being used in the manufacture of metallic aluminium.

The Bureau of Mines is at present engaged in research concerning benefication of low-grade bauxite ores by the removal of some of the silica through flotation. Up to the present this study has not reached a point where definite conclusions can be drawn as to all types of ore, but laboratory experiments indicate encouraging results. Should this research develop the possibility that the silica content can be substantially reduced, appreciably more of the reserves of bauxite ore would be suitable for production of metallic aluminium.

Bauxite used for cement and oil-refining purposes has a lower alumina requirement (52 to 56%), although the silica tolerance must be about the same as for metallic grade ore. Bauxite for cement, however, may contain considerably more iron oxide. Consumption for these purposes is small.

Bauxite Reserves

The United States bauxite reserves are discussed in this report in considerable detail, a summary of the total reserves being given in Table II. The figures represent tonnages calculated from drilling and other exploration and development data reduced to a "mined and dried" basis.

ESTIMATED BAUXITE RESERVES OF THE UNITED STATES.

Reserves, Total Long Tons.	Alumina Content, %
9,343,000	+ 55
8,898,000	50–55
8,439,000	45–50
2,348,000	30–45
29,028,000	+ 30

All commercial grades of bauxite must contain 50% or more alumina. By far the largest consuming use requires 55% or more. It is evident that the requirements of the normal market restrict the use of bauxite to ore of high grade. For this reason, the common commercial grades should not be used in classifying reserves.

It has been found from study of many hundreds of analyses of bauxite ores that the silica content rises as the alumina content drops. This suggests classification of reserves upon the basis of alumina content alone. Re-examination of a large number of analyses from this point of view disclosed that bauxite containing more than 55% alumina seldom exceeded 6 or 7% silica, and the iron content was comparatively low. In ores with 50 to 55% alumina the silica content seldom exceeded 15% and often was not more than 10%. The iron content varied, but usually was not excessive.

In ores containing less than 50% alumina, down to 45%, the silica present usually exceeded 15% and occasionally was as much as 30%. However, the iron content in these ores usually complemented the silica content. With high-silica analyses the iron was proportionately low, and vice versa. In bauxites carrying less than 45% alumina, either or both the silica and iron contents will usually be high.

The fact that laboratory experiments have shown that some bauxite ores with as much as 12 to 15% silica can be concentrated to 6% or lower by flotation supports the suggestion that such ores may be classified according to alumina content for reserve purposes. For purposes of this report, bauxite reserves are graded as follows :—

Grade.	Alumina, %	Silica, %
A	+ 55	Less than 7
B	50 to 55	„ 15
C	45 to 50	„ 30
D	30 to 45	High in silica and iron

A reference to Table II gives an estimate of more than 9 million tons of bauxite suitable for the manufacture of aluminium without further concentration. In addition, the table shows nearly 9 million tons of grade B ore, which under emergency conditions may be used for aluminium after washing or concentration to reduce the silica content. This conclusion is verified by various operating companies and also by results of laboratory tests which disclosed that some ores containing as much as 12 to 15% silica could be concentrated by flotation methods to 6% or less. Not all ores were found amenable to this benefication, and no conclusions were reached as to processing costs. However, it is presumed that once the method is found to be technically feasible the economic factors will be solved satisfactorily, as the flotation process itself is well known and well established as economical for many different ores.

TABLE III.
BAUXITE SHIPPED FROM MINES AND PROCESSING PLANTS IN THE UNITED STATES, BY CONSUMING INDUSTRIES.*
In Long Tons (Mined and Dry Weight).

Consuming Industry.	1936.		1937.		1938.		1939.		1940.	
	Tons.	%	Tons.	%	Tons.	%	Tons.	%	Tons.	%
Aluminium .	194,764	53	209,476	48	144,208	49	161,008	46	214,194	48
Chemical ...	74,741	20	79,150	18	63,350	22	79,536	23	80,933	18
Abrasive ...	98,069	26	135,849	32	74,614	26	82,326	23	128,818	29
Other†.....	2,401	1	8,189	2	10,159	3	26,466	8	25,253	5
Total ..	369,975	100	432,664	100	292,331	100	349,336	100	449,198	100

* Bureau of Mines Minerals Year Book, Review of 1940.
† Includes oil refining, refractory, and other uses.

The concentration of grade C ore, however, is not known to have been attempted commercially, and, unless it is subsequently found to be amenable to concentration or can be used in some process other than those now in commercial use, it is doubtful if grade C ore can be considered a source of metallic aluminium. This applies to grade D ores also. It appears, therefore, that grades A and B must be depended on as a domestic supply of aluminium ore. These grades, however, must also supply consumers of bauxite for other purposes. Table III shows that in 1938, 1939 and 1940 the domestic bauxite consumed for purposes other than metallic aluminium was roughly 148,000, 188,000, and 235,000 long tons, respectively, or 51, 54, and 52% of the domestic production. It is of special interest to note that the use for abrasive purposes rose from 82,000 tons in 1939 to 129,000 tons in 1940, probably reflecting increased use of abrasives in the defence effort. It is not at all unlikely that during continuation of defence preparations the domestic need for bauxite for purposes other than metallic aluminium may reach or exceed 250,000 long tons annually, most of which probably will come from domestic mines.

If this quantity is added to the estimated requirement of 2,850,000 long tons for metallic aluminium, it is evident that 3,100,000 long tons will be needed annually, beginning July of this year. Reserves of grades A and B bauxite, from which this supply must come, should it become impossible to import the ore, total roughly 18 million tons.

Should it become necessary under emergency conditions to prohibit imports, United States reserves would be sufficient to satisfy defence needs as now envisaged for 5·8 years, but thereafter the greatly expanded aluminium industry must depend entirely on foreign bauxite or resort to other raw materials, such as alunite or high-grade clays at greatly increased cost. Although numerous processes for the utilisation of alunite and clay for aluminium manufacture have been suggested, the fact remains that at present no such process has been proved commercially successful.

In a recent survey of United States alunite reserves, it was estimated that 2,377,475 short tons of alunite was available in rock containing 50% or more alunite. This represents roughly 700,000 short tons of recoverable alumina, or 350,000 tons of metallic aluminium—five months supply at anticipated national requirements. If alunite rock containing as little as 30% alunite could be utilised, the amount available would be 9,434,000 short tons, equal to 1,400,000 tons of metal.

Although the results of present research indicate the probability that rock containing 50% alunite (18·5% Al_2O_3) can be utilised for metallic aluminium, it is extremely doubtful whether rock containing 30% alunite (9% Al_2O_3) can be utilised. On the other hand, if it can be demonstrated that rock containing 18·5% alumina can be utilised commercially, it seems pertinent to assume that with proper modification the extraction process used for alunite of that grade could be used with at least some success on grades C and D bauxite ores and thus extend the life of domestic resources 2 or 3 years.

If processes can be developed for utilising alunite and low-grade bauxite, as seems probable from research studies, and an opportunity is afforded for their commercial demonstration, possibly such stimulus may encourage initiation of new processes or modification of others whereby clays may eventually become the domestic source of aluminium if foreign supplies are cut off. Metallic aluminium has been made experimentally in the laboratory from high-grade clays; Singer[1] reports that such clays have been utilised on a minimum pilot-plant scale for manufacture of aluminium. However, the utilisation of clay in the United States, up to the present, has presented too many technical and economic problems to make it a competitor of bauxite as a raw material for aluminium.

1 F. Singer. "Methods of Extracting Alumina from Clay." *Brick and Clay Record*. 1939, **94**, pp. 54–58.

Correspondence

Annealing Nickel-Chromium Steel Forgings

The Editor, METALLURGIA.

Dear Sir,

Having come across the same problem in American literature, I was much interested in the note by Mr. Bernard Thomas, in your November issue of METALLURGIA, a copy of which has just reached me. Thus, for instance, Dr. Woldman states, in *Iron Age* of May 15, 1941, page 61 :—

> "In some steel it is difficult to break down the austenite to give the hard martensite desired, leaving a soft skin on the gears. This austenitic layer is often considered a decarburised skin, but it is not. It may run 0·010–0·040 in. thick. By packing the gears in ice for 10 days the retained austenite will break down. Liquid air will accelerate the process, or a long tempering at 300° F. will accomplish the same result. On the other hand, too rapid cooling of S.A.E. 3312, after carburising, will produce too much martensite and give a surface with a hardness of 50–55 Rc—entirely too hard to machine."

To overcome this condition, Dr. Woldman suggested a 40-hour cooling period from the carburising heat.

In December, 1941, *Metal Progress* there appeared the following short note under "Economics of Metal Use," by Mr. Fred McLeary, of Chrysler Corporation :—

> "If surface austenite is desired, a surface carbon of 1·15% or over is indicated. Austenite in the quenched structure means Rockwell hardness C–57 max., which scores rather easily. Modern inability to ensure a running-in period does not give time to cold-work austenite surfaces slowly. To keep austenite to a minimum and hardness well above C–60 carbon should be 1·10% max."

Although these two articles refer particularly to the high nickel carburising steels, you would seem to have a similar condition with 4S11 steel, due to the high nickel content and resulting sluggish austenite-martensite transformation. Probably a long preliminary tempering at 300° F. after hardening would be most effective in breaking up the austenitic skin.

May I express, on behalf of myself and co-metallurgists, our best wishes to you metallurgists in Britain. We know you are doing a swell job under tough conditions. May the New Year bring victory and a lasting peace.—Yours very truly,

L. F. TRAIN (B.Sc.),
Metallurgist.

December 26, 1941.
Dundas, Ontario, Canada.

Dear Sir,

I was very pleased to receive the above letter from Mr. Train in connection with a note of mine which appeared in the November issue of METALLURGIA. It is refreshing to think that even war on either side of the Atlantic fails to prevent discussion on technical matters.

In regard to the views expressed by Dr. Woldman, it is, as Mr. Train will know, a very difficult matter to resolve austenite satisfactorily under the microscope, and while it may often be present, the characteristic acicular structure of the martensite is apt to obscure the former constituent.

Dilatometer recording on the heating of a quenched steel indicate a constitutional change at a change of around 180° C. (approx. 350°–360° F.), and I have always associated this change with the breakdown of austenite to martensite, satisfying myself on the point by the slight increase in diamond hardness after treatment. This, of course, confirms that austenite is softer than martensite, and it is unfortunate that many people have the mistaken idea that the softer skin is due to the decarburised layers.

Rather than adopt the suggestion of Dr. Woldman of a 40-hour cooling period from the carburising heat, one would suggest a normal withdrawal and air cooling down to, say, 700° F. and then reheating to an annealing temperature around 1,200°–1,250° F., which, for practical purposes, would, I suggest, be not only more satisfactory, but more economic than a long cooling period.

Many thanks to Mr. Train for his New Year wishes, which are heartily reciprocated. With the help of Canada and that of the other members of the British Commonwealth of Nations and of our Allies we shall soon see victory and peace.—Yours sincerely,

BERNARD THOMAS,
Managing Director.

January 26, 1942.
Midland Heat Treatments, Ltd.,
Wolverhampton.

[May we express our thanks to the above readers for their useful correspondence. We recognise that, in this period of emergency, it is not easy to find time to discuss problems encountered and to suggest solutions, but we shall be glad to find room in our journal for correspondence on metallurgical matters that are of general interest.—EDITOR].

Notes on Industrial Nitrogen Atmospheres

By O. G. Pamely-Evans, B.Sc., A.I.C.

In many processes, notably in heat-treatment, the need for control of the atmosphere under which they are carried out is increasing the use of "inert atmospheres." Probably the most ideal for many forms of heat-treatment is an atmosphere composed of nitrogen, and these notes on industrial nitrogen atmospheres will be of interest.

NITROGEN is a gas ideally suited for the use as an "inert atmosphere" in reactions which have to take place in absence of what is empirically called "air," although by this loose term is meant the chemically active part of "the air," or oxygen. Nitrogen is plentiful, the only impediment to its use in this connection being that naturally it is intimately mixed with the very gas which its use is intended to exclude. Hence methods have been evolved for the separation of oxygen and nitrogen, and it is proposed to deal here solely with those methods which are concerned with the production of pure ("oxygen-free") nitrogen, the fate of the oxygen being immaterial.

There is the purely physical separation of the two gases by fractional distillation of liquid air, the nitrogen being a fraction which is collected at a lower temperature than the oxygen. This method serves as a crude separation, but the amount of oxygen left in the purest specimen of nitrogen makes it useless for some purposes. It may be further purified by essentially chemical processes, which may be divided into three main groups :—

(1) Methods employing easily oxidisable compounds in appropriate conditions.
(2) Methods using metals in the elementary state.
(3) Methods employing a combination of the above processes, the compounds usually being used to regenerate the metal as fast as it is oxidised.

These may be dealt with in order :—

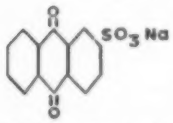
Methods Using Easily Oxidised Compounds

These are multifarious, nearly every works employing oxygen-free nitrogen having some modification of its own. The most notable, however, are those enumerated below :—

(*a*) Binder and Weinland has shown[1] that the deep-red solution formed when ferric salts and catechol are mixed in alkaline solution contains salts of an acid $H_3(Fe(C_6H_4O_2)3)$. If ferrous sulphate be used instead of ferric salts,[2] no colour is produced, but oxygen is rapidly absorbed to give the red colour.

(*b*) By the Siemens-Schuckertwerke process, in which the gaseous mixture is passed through a solution of the following composition :—

$Na_2S_2O_4$	(True sodium hyposulphite)	160 parts.
NaOH	(Caustic soda)	120 ,,



(Sodium anthraquinone-β-sulphonate) 20 ,,

H_2O (Water anthraquinone) 11 ,,

which effectively absorbs oxygen, probably with the formation of di-hydroxy anthraquinone compounds, it being a peculiarity of the anthraquinone *mono*-sulphonic acids, to give di-hydroxy anthraq tinones on treatment with a caustic alkali, absorption of oxygen being necessary.[3]

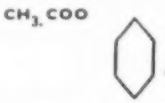
(*c*) That credited to E. Romanell, in which a mixture of hydrogen and the gaseous mixture is burned in the outer of two concentric cylindrical chambers. The product, consisting of nitrogen and water vapour, with small quantities of hydrogen and oxygen, is cooled, so that the water condenses, and the gas remaining is let into the inner cylindrical chamber, which contains heated spirals of copper, to remove the last traces of oxygen.* The relatively cold gas passing through this chamber cools the surrounding combustion chamber.

(*d*) The method developed by Kautsky and Thiele. In this method oxygen is removed from the mixture by forcing the gas through a porous membrane immersed in a solution of sodium hyposulphite ($Na_2S_2O_4$), intimate contact between all parts of the gas and the solution being thus ensured. The product is stated by the originators of the method to contain less than 0·0007% of oxygen. This is a method of much higher efficiency than the previous two.[4]

(*e*) Jones and Meighan investigated the absorption of oxygen by alkaline pyrogallic solutions. They state that such solutions absorb oxygen freely, forming a dark brown liquid—carbon monoxide is evolved if the caustic-soda solution has a specific gravity of less than 1·3. All sodium pyrogallic oxide solutions evolve carbon monoxide if the oxygen content is more than 95%.

A reagent designed to evolve the minimum of carbon monoxide is prepared by dissolving an amount of caustic soda in its own weight of water, and adding five parts of this solution to two parts of a solution containing 1 grm. of pyrogallol to each 3 grms. of water.[5]

(*f*) Henrich designed a still more active absorbent. It is a suspension of 11·4 g. of powdered hydroxyquinal tri-acetate



(which is prepared by the action of acetic anhydride upon *p*-benzoquinone) in 20 c.c. of water, shaken in an atmosphere of hydrogen with a concentrated alkaline solution consisting of 17·4 g. of potassium hydroxide (or the equivalent, 6 mols. of caustic soda), and then diluted with 130 c.c. of water.[6]

(*g*) Gomberg's discovery of the trivalent-carbon compounds of the type of triphenyl methyl $C.Ph_3$ has been made use of.[7] These compounds vigorously absorb oxygen from gaseous mixtures with nitrogen, giving peroxides of the type—

$$CPh_3. \qquad O—O—CPh_3$$

(*h*) Flight (1882) The gas mixture may be vigorously shaken with precipitated ferrous hydroxide, Fe (OH) 2 or manganous hydroxide Mn $(OH)_2$ in presence of water, when oxidation occurs to the ferric and manganic hydroxides respectively, with absorption of oxygen.[8]

(*k*) F. Hamon, Andre Mayer and L. Plantefol perfected some delicate tests for oxygen, (see end of paper) and also a method for obtaining very pure nitrogen, practically oxygen-free (less than one part in $1·7 \times 10^8$) by passing the gas through a Gautier phosphorus-purifying bottle, filled with fused white phosphorus, and joined to a Bender-Hobein B bubbling apparatus containing 15% caustic-soda solution and two similar containers of saturated H_gCl_2, to retain gaseous products of the reaction. The method works extremely well, and yields about 1–2 litres of purified nitrogen per hour.[9]

1 A. 1912. i, 184–445.
2 Ber. 1913. 46, 255–259.
3 A.G. Ger. 488, 179, Feb. 5, 1926.

*This final stage would make the process apparently more suitable for inclusion in the second main group, but there is, in fact, considerable overlapping of the types.

4 *Z. Anorg. Chem.* 1926. 152, 342–346.
5 *Journal of Industrial and Engineering Chemistry.* 1919. 11, 311.
6 *Berichte der Deutschen chemischen Gesselschaft.* 1915. 48, 2066.
7 *J.A.C.S.* 1900. 22, 757.
8 Watts' Dictionary of Chemistry. (Morley and Muir.) Vol. III, p. 556.
9 Ann. physiol. physico chim. biol. 6, 452–63. (1930.)

(*m*) Partington suggests the use of moist iron filings, liver of sulphur, phosphorus at ordinary temperatures, acid chromous chloride solution, and cuprous chloride in hydrochloric acid or ammonia solutions.

$$4\,Cu.Cl. + 4H\,Cl + 02 = 4\,Cu\,C\,12 + 2\,H_2O$$

These methods leave from 0·2% to 2% O_2.[10]

(*n*) Asteverts and S. Halberstadt experimented with a method of removing oxygen from gaseous admixtures with nitrogen, using six types of washers containing aqueous Cr.Cl.2 (method suggested by Berthelot). Those in which the mixed gases entered through fine filter plates were found to be the best.[11]

(*o*) A. A. Harwood experimented with the use of Carstanjen's (1877) compound (an oxaluramid) and alkali to absorb oxygen. He found that 1 grm. molecule of the compound absorbs 11,190 c.c. of oxygen, the process being rapid. 2 grms. of the substance took 7 mins. to absorb 0·1163 grms. of oxygen.[12]

This is a short survey of the types of compound method for removal of oxygen. The second group comprises most metals, since all known metals are directly oxidisable in certain conditions. Considerations of cost, of course, limit the choice to the few fairly cheap metals, and the variations in the method are chiefly in attempts to use these metals as efficiently as possible.

Methods Using Metals

Years ago Brunner and Spencer used red-hot reduced iron, through which the gaseous mixture was passed. This is, of course, extremely effective, provided a sufficient length of heated iron is used, but reduced iron is costly. Copper is said to be the best metal in this connection, particularly in the form of turnings, which offer a very large surface. It was used and recommended by Dumas, Boussingault, Bunsen, von Joly, Ledue, Welton, Franke and Fenke, Carius, Trelfall, and the Cyanid Gesellschaft. Deslandres used molten sodium.

The methods may be summarised as below :—

(*a*) *Alkali-Metals.*—Used molten (Deslandres) and also in the liquid-alloy form, such as the sodium-potassium alloy, which is liquid at ordinary temperatures. It is absolutely essential in these cases that a trace of moisture be present. Actually, it seems that pure water alone does not suffice, but some (unspecified) electrolyte dissolved in the water is necessary to start the reaction. Only the minutest traces of either water or electrolyte need be present.

(*b*) *Copper and Iron.*—The processes using these metals are very many, but a few outstanding examples are cited below :—

(1) In that developed by Thoressell and Lunden the oxygen is absorbed by iron, the heat set free being used for the regeneration of the absorbent, thus reducing the additional heat required.[13]

(2) This method by Kendall is described as using a pyrex tube containing as heating unit a nichrome spiral surrounded by mica and a cylinder of copper gauze. All traces of oxygen (and hydrogen) are removed from the nitrogen, and water vapour may be freely passed through the tube without the slightest trace of formation of hydrogen being detected. Regeneration of the copper with hydrogen requires only a few minutes.[14]

(3) A. Sieverts discusses the mechanism of absorbtion for oxygen ($^{\circ}N_2SO_2{}^{\circ}H_2$) in various metals and alloys, both isobars and isotherms being plotted.[15]

(4) E. A. Ashcroft in 1918 examined the active alloys found by Grube in 1905,[16] and found remarkable properties in those of the magnesium-lead type, particularly those containing 5% to 50% of magnesium to 95% to 50% of lead. Calcium alloys were similar, but much less reactive, and likewise lead appeared to be the best base metal for the alloys. Zinc and magnesium in similar proportions appear to be much less easily oxidised than zinc or magnesium alone, 15% magnesium to 85% lead will rapidly and completely oxidise even in the cold if exposed to dilute oxygen and moisture, to a jet black powder of magnesium hydrate and lead suboxide or its hydrate.

X Mg $(OH)_2$ + X Pb_2O (H_2O) X. A few hours completes the reaction. It must be noted that the reactions do *not* decompose the water present (evolving hydrogen) it adds on after oxidation, but the reaction will not occur in its absence. Excess alloy is taken to ensure the complete removal of oxygen from a gaseous mixture, but no large excess is required, the reactions being complete without it. It is also not necessary to crush the alloy finely (although it is both brittle and friable). Large pieces rapidly oxidise and fall to a powder in moist air at normal, higher, or lower temperatures. Reactions are :—

$$(a)\ Mg + O + H_2O = Mg\,(OH)_2$$
$$(b)\ 2\,Pb + O + H_2O = Pb\,(OH)_2$$

The reactions are slow at first, accelerate, and are complete in a few hours, the hydrates formed being stable up to 200° C. Every trace of oxygen may be removed from a gaseous mixture in a confined space, alloys of 15% magnesium being preferable, those of higher magnesium content (35% and upwards) not oxidising so readily in the cold.

The preparation of these alloys is simple. Magnesium and lead may be readily fused together under a cover at 700° C. to 800° C., and after mixing thoroughly may be cooled out of contact with air, when complete alloy will be found to have taken place. Alternatively, the magnesium may be precipitated from its salts into the lead by using alkali metals, or alkali metal alloys. A very cheap method where electrical power is plentiful is to electrolyse anhydrous $MgCl_2$ over a cathode of molten lead. The method of using these alloys to remove oxygen from a gaseous mixture is merely to enclose them in a vessel with the gases for a few hours.[17]

Combination of the Above Processes

The third class is that in which both a metal and some regenerative process are employed. These chiefly use copper as the metal. They have the advantage of not requiring replacement of the relatively expensive metal, and in many of them the by-products are used (as the nitrogen in Lupton's method).

(1) A solution of cuprous chloride in hydrochloric acid readily absorbs oxygen, with formation of cuprous oxychloride. The greenish brown solution of this salt may again be reduced by keeping copper foil in it :—

$$Cu_2Cl_2 + 2\,H\,Cl + O = 2\,Cu\,Cl_2 + H_2O$$

(2) Berthelot suggested partly covering about 200 grms. of pure copper turnings with aqueous ammonia in a 10–14 litre flash, closed with a cork carrying a safety funnel and a delivery tube stopped with a caoutchouc cap, and shaking from time to time. The oxygen is completely removed, and the nitrogen obtained by pouring in water previously treated with ammonia and copper.[18]

$$2\,Cu + O_2 + nN_2 = 2\,CuO + N_2$$
$$3\,Cu\,O + 2\,NH_3 = 3\,Cu + 3H_2O + N_2$$

(3) Von Wartenburg enclosed the gases in a steel bomb at 100 atmosphere pressure, with metallic copper and an ammoniacal solution of ammonium chloride for 1 hour. The residual oxygen is only about 10·4%.[19]

(4) Lupton stated that nitrogen in quantity is generally prepared by leading air over copper turnings in a glass tube. Oxide of copper is formed and N passes over alone.

$$(2N_2 + O) + Cu = CuO + 2N_2$$

A considerable length of copper must be heated and the reaction comes to an end when the copper is somewhat thickly coated with oxide. B. Harcourt suggested that if the air was mixed with ammonia by bubbling through a strong aqueous solution the copper oxide would be reduced

10 Textbook of Inorganic Chemistry. Partington. Chap. on O2.
11 *Chem. Fabrik.* 1930. 201–2.
12 *J. Am. Pharm. Assoc.* 20, 17–20. (1931.)
13 Pat. Swed. 51, 932. Jan. 14, 1922.
14 *Science.* 1931. 73, 394–397.
15 *Z. Metallkunds.* 21, 37–46. (1929.)
16 *Zeitog, Anorg. chem.* 1905. 44, 117.
17 Trans. Faraday Soc. 1918. Vols. 13, 14, pp. 271 *et seq.*
18 Bulletin de la Société de Paris (23, 13, 314).
19 *Z. Elektrochem.* 1930. 36, 295–7.

as fast as formed and the reaction would be continuous as long as the solution contained any ammonia. Air and ammonia would thus give nothing but water and nitrogen.

$$3(2N_2 + O) + 2NH_3 = 3H_2O + 7N_2$$

On trying the experiment he found that about 3 in. of copper turnings, heated by an ordinary Bunsen burner, served to replace the long furnace and combustion tube of the ordinary method, and that the slightest excess of air shows itself by tarnishing the surface of the turnings. By this method he many times prepared nitrogen so pure that a stream of it did not alter the surface of fused potassium.[20]

C. van Brunt devised an apparatus for use in the (Drawing) laboratory, using Lupton's method. It uses equal volumes of saturated $(NH_4)_2CO3$ and NH_3 solution (Badger modified it to use NH_3 and sat: $N H_4 Cl$) as the circulating liquid (which is kept in circulation by the gases forced in). A clip is used to regulate the flow. The copper turnings are heated in a furnace. Other sundry methods include solution of oxygen in molten silver (it does *not* combine) which dissolves about twenty times its own volume of oxygen.[21]

Hulett passed the gases, mixed with hydrogen over heated copper, followed by condensation of the water formed. This is very effective. Metzer added a combustible gas (e.g., H_2) and brought the mixture under high pressure in contact with carborundum at about 400° C., so as to maintain the combustion, followed by condensation. Dumoulin mixed 100 volumes of the gas to 42 volumes H_2 and passed over heated Pt black after first removing CO_2.[22]

Benton and Drake have recently investigated the adsorption of oxygen by activated finely divided silver. It takes place slowly at low temperatures, increasing rapidly with rise of temperature, the oxygen being adsorbed irreversibly. Above 60° C. finely-divided reduced silver reacts with oxygen to give the oxide, the heats of formation and dissociation being 22,000 calories and 35,000 calories respectively. This provides a good method for removing oxygen from its mixtures with nitrogen at temperatures above 160° C.[23]

Note on Tests for Oxygen

These are necessary for the type of work outlined above, and need not necessarily be quantitative, provided the limit concentration below which oxygen will not respond to the test be known. A negative result will then enable a more sensitive test to be applied. The methods used are many and various, but the more generally useful are outlined below.

1. Anastasios C. Christomanos prepared a sensitive reagent for oxygen by the action of PBr_3 on solid copper nitrate, or on a solution containing not more than 10% of the salt. The mixture is cooled, shaken with ether (when it gradually becomes colourless) and preserved in sealed tubes. On shaking with oxygen the ether goes green, and the lower layers reddish-purple, both colours finally disappearing, when the reagent can be used again.[24]

(2) Binder and Weinland used their mixture of ferrous sulphate and catechol in alkaline solution (see above) as a very delicate test reagent for oxygen, the production of the red-coloured salts of H_3 Fe $(C_6H_4O_2)_3$ being very easily observed.[25]

(3) V. I. Panus Yuk replaced pyrogallol as a test reagent by a filtered solution of 35·4 grms. of $FeSO_4$ in 120 c.c. of water, to which 10 g. of tartaric acid and 45 c.c. of 25% aqueous ammonia solution are added. A dark colouration is produced by traces of oxygen.[26]

(4) Ambler compared the colour imparted by oxygen to alkaline pyrogallol to that of iodine solutions of known strengths previously calibrated, thus avoiding instability of standards of pyrogallol.[27]

(5) A simple test is to remove a sample of the gas and mix it with nitric oxide.

$$2NO + O_2 = 2NO_2$$

The red colour produced by the NO_2 may be detected by measuring the absorption of a beam of light passing through the gases by photometric methods.

(6) Chromous chloride solutions change from blue to green with traces of oxygen.

(7) Leuco-bases of vat dyes, such as indigo, may be used, producing strong colours on oxidation.

(8) F. Hamon, Andre Mayer, and L. Plantefol designed a fairly good quantitative test. The principle involved is the oxidation of manganous to manganic hydroxide; this in acid solution forms manganic acid, which sets free I_2 from KI, starch serving as an indicator. By a suitable apparatus the method will detect 10^{-7} g. of oxygen in a volume of 10 litres of gas at atmospheric pressure. They also showed that white phosphorus becomes luminescent when it is exposed to a gas containing more than one part of oxygen in 10^5 to 10^6 parts of gas.[28]

The passage of the gas over a surface of a molten alkali-metal was used by Lupton to detect traces of oxygen. Dimming of the bright surfaces instantly shows the presence of oxygen.[29]

20 *Chem. News*, 1876. Vol. 33, p. 90.
21 Neath. Inorg. Chem., p. 190.
22 *L. Institut.* 185, 11.
23 *J. Am. Chem. Soc.* 56, 255. (1934.)
24 Chem. Centre. 1906, ii, 1139–1140, from Vech. Ges Deu. Naturf Aerzte. 1905, ii, 76–77.
25 Ber. 1913. 46, 255–259.
26 *Ukrain Khem Zhur.* 7 Wiss. Teil 94–7. (1932.)
27 *Analyst.* 59, 14–15. (1934.)
28 Ann. physiol physico chim. biol. 6, 452–63. (1930.)
29 *Science.* (1931.) 73, 394–397.

The Future of the Railway Oil Engine

THE railway oil engine is built in powers of 45 to 2,200 b.h.p., in single units, runs at speeds of from 400 to 2,100 r.p.m., has specific weights of 11 lb. to 65 lb. per b.h.p. in normally aspirated types, and operates at piston speeds of 900 to 2,200 ft. per min., and m.e.p.'s of 65 lb. to 95 lb. per sq. in. Pressure charged models have specific weights as low as $8\frac{3}{4}$ lb. per b.h.p. and working m.e.p.'s of 100–125 lb. per sq. in. These engines cover all types of railway service from occasional light shunting to high-speed intensive passenger traffic, but as oil engines of normal patterns must work in conjunction with a transmission system for traction purposes, there is not always the wide variety of type between different duties which might be expected. Nevertheless, there are certain well-defined classes covering different installations, and nowadays all are more or less special railway types. But in the loco-tractor, shunting, and light railcar fields possibly less modification is required to stationary and road transport engines to suit them for railway duties, with the exception that shunting locomotive engines must be capable of withstanding continuously loads that fluctuate violently and frequently. It is the two very special railway classes to which Mr. Brian Reed directs particular attention in a recent paper to the North-East Coast Institution of Engineers and Shipbuilders.

The first of these two classes is the lightweight high-speed railcar and fast-train engine of 200 to 750 b.h.p.; the second is the high-power locomotive engine of 900 to 2,200 b.h.p. Neglecting North American practice, which is a law unto itself, modern engines of the high-power locomotive type are limited to two makes—viz., Sulzer and M.A.N. The Sulzer engine is built in two sizes: a single-bank engine of 1,200 b.h.p., and a twin-bank design of 2,200 b.h.p. Only single-bank engines are made by M.A.N., and are limited

in output to 1,000–1,050 and 1,300–1,400 b.h.p.; when larger outputs are required two engines are mounted stagger fashion on a common underbed. Both Sulzer and M.A.N. makes are pressure charged on the exhaust gas-turbine principle and run at 700–750 r.p.m.; M.A.N. favours a completely welded steel under frame, crankcase and cylinder block; whereas Sulzer uses a combination of cast steel and welded steel. The author emphasises that it is only the perfecting of the exhaust-gas pressure-charging system that has made such engines as these practicable. In his view, the locomotive of any type is the wrong unit for passenger traffic except in a few cases, and he believes that in the future most passenger trains of new construction will be composed of one or more railcars or multi-car formations coupled together in multiple-unit and driven by one man. Should this come to pass, it is the lightweight high-speed engine which will be built in large numbers, and every vehicle or vehicle-set will have its own motive power.

The engines already used in modern railcars and high-speed trains are, in general, of the six-cylinder vertical or 12-cylinder V patterns. In their naturally aspirated forms they weigh 11 lb. to 18 lb. per b.h.p. in the dry condition, and on the top power setting, run at 1,350 to 1,500 r.p.m., have m.e.p.'s of 85 lb. to 95 lb. per sq. in., and have piston speeds of 1,650 to 2,100 ft. per min. Pressure-charging reduces the specific weight to 9–13 lb. per b.h.p., and increases the m.e.p. to 110–125 lb. per sq. in. Signs have not been wanting, however, that a widespread change may be made in the build of engine used for railcars and high-speed trains. The engine is merely part of a traffic machine, and it is essential that the maximum amount of floor space should be devoted to revenue earning. To that end horizontal engines were developed, and although they had not been used to a very large extent prior to the war, a good many of the problems associated with their satisfactory operation and maintenance had been solved by the end of 1939, and there are indications that the use of the "Flat" or "Pancake" or "Boxer" engines, to give them their various appellations, will spread rapidly after the war.

The author discusses the inherent defects and advantages of the oil-engine for traction; three principal methods of advance in oil-engine technique; direct drive, progress in engine performance, and improvement in maintenance; possibilities of higher speed, increased m.e.p., pressure-charging and its cylinder events compared with natural aspiration, the Kadenacy principles, and improved construction; engine life and the two general types of maintenance; the paramount importance of high-speed engines of the future being able to burn what are now regarded as inferior fuels, and possible changes in design to meet this requirement.

In his conclusion, Mr. Reed suggests that the high-speed railway oil engines of post-war years will be more or less standardised as four-stroke pressure-charged or two-stroke Kadenacy types, burning heavy fuels, and that although vertical and V models will continue to be built, the use of horizontal models will become more and more extensive. Neglecting the models up to 150–200 b.h.p., which are derived more or less from road-transport practice, it is suggested that the most popular power ranges will be 250–300 b.h.p., 500–700 b.h.p., and 900–1,000 b.h.p., all with m.e.p.'s of 120–130 lb. per sq. in., a rotational speed of 1,500 r.p.m., a piston speed of 1,700–1,800 ft. per min., and a specific dry weight of 9 lb. to 12 lb. per b.h.p. The order of flexibility required will be economical operation from 500 r.p.m. to 1,500 r.p.m., with a fuel consumption over this speed range and with a load variation of 4 to 1 never exceeding 0·40 lb. per b.h.p.-hour with light Diesel oils, or about 0·44 lb. with heavy oils, and with respective three-quarter to full load consumptions of 0·36 lb. and 0·40 lb. per b.h.p.-hour. Such engines will have to run at least 100,000 miles between general overhauls, or a million miles if the travelling fitter system of maintenance is used.

As regards main-line locomotive engines, the present single-bank and twin-bank four-stroke pressure-charged vertical build is likely to be perpetuated, although the use of Kadenacy two-stroke models of the same general type, running at 700–1,000 r.p.m. and with 12 in. cylinders, should be attended with no difficulties. Speed is likely to increase from the present 700–750 r.p.m. to 900–1,000 r.p.m. without any increase in total weight or any decrease in m.e.p., which will not only reduce the specific weight of the engine, but will also bring a better transmission, and will result in engines giving 3,000 b.h.p. or more becoming practical propositions and simplifying the design of many main-line locomotives. Despite certain attractions, it is not likely that any form of direct drive will be used in more than isolated cases in the immediate post-war years.

Zirconium

By Stephen Coleman

Although the common metals find ever-increasing applications, they often fail to withstand exceptional conditions of service; in such cases the use of rarer metals becomes an economic proposition. While not a recent discovery, zirconium is now being gradually applied in such cases.

NO one who deals with refractories can afford to ignore the superior properties of the oxide "zirconia," for its high melting-point and its inertness towards both acids and alkalies give it a definite advantage over many of its class. It can be applied as a protective coating to other cheaper refractories, while tubes of the material or of the crude mineral form "zirkite" have been used, especially in America, in the research laboratories of engineering concerns, particularly for erecting experimental electric furnaces. The oxide has found considerable application in the glass industry in place of the more expensive quartz for lenses, and as an opacifying agent in iron enamels. As a filler in the rubber industry, as a catalyst in the chemical industry and in other directions, the oxide of this metal has assumed great importance.

Zirconium can be prepared as a powder and when liberated by the aluminium method has to be treated in a similar way to tungsten—viz., it is pressed into bars, freed from gaseous inclusions, forged, swaged and rolled into sheets. As a pure white powder, it is an excellent paint base. It has been tried with good results as a substitute for tin oxide as an opacifier in enamels. It has the added advantage that enamels prepared from it exhibit acid-resisting qualities.

There have been two chief objections to its use in the past. First was the difficulty experienced in obtaining the oxide free from iron, and second, the lack of plasticity in the body prepared from ground zirconia combined with excessive shrinkage after firing. Both these difficulties, it has been found, can be overcome. The shrinkage is diminished by using zirconia previously calcined; while ore, relatively free from iron, is now available in immense quantities in Brazil.

Zirconia deposits were found in this South American

State some few years ago, and American geologists and mining interests undertook a scheme of exploration work. This resulted in the discovery of big deposits, and there are at present several million tons of ore in sight on the surface alone. These deposits are classified as "favas" and "amorphous." The former are rounded masses produced by the rolling of fragments from veins. As extraneous matter has thus been detached, they give a high percentage of ZrO_2 (90–95%). Some of the "favas" have been derived from very pure oxide found in a mamillary form (baddeleyite). Zirconia in an amorphous variety forms the bulk of the ore extracted. It generally contains a certain amount of unaltered silicate, and it is this which is the principal factor in lowering the percentage of ZrO_2. Iron is present in varying amounts.

These large deposits attracted attention to the question of extracting the metal from the mineral. The United States Bureau of Mines introduced an extraction process using sulphuric acid; the purified zirconium oxide being then precipitated from the solution. Fusion processes followed, especially when dealing with the mineral silicate known as "zircon," the oxide being again precipitated from an extract of the fused material. Then came the question of winning zirconium metal economically from the purified oxide. After the more expensive calcium process had been worked out, in which metallic calcium displaced zirconium when heated with the oxide, the aluminium method was perfected, the latter metal combining with the oxygen just as it does in thermite, and liberating zirconium of 99·5% purity.

Practical Uses

With the success of the extraction problem research and experimental work have resulted in the application of zirconium to engineering practices in many directions. It has been found, for instance, that zirconium will form alloy with all the familiar metals except tin and lead. Of a silvery-white colour, the metal is extremely hard and highly resistant to atmospheric corrosion. Its specific gravity is high, and in its natural state it is very refractory.

It has been found that zirconium-steel alloys have many properties to commend them. Armour-plate manufacturers have included it in their steels for increasing the tensile strength, up to 0·34% being the proportion, together with 3% nickel. In chemical engineering, the alloys of the metal have shown much promise, certain alloys show great resistance to hydrochloric and sulphuric acids. In the electric lamp industry, filaments made from alloys of zirconium show a superior radiation when raised to the same temperature as tungsten filaments.

Economising in the Use of Manganese in the Open-Hearth Process

MANGANESE is one of the most important minerals, mainly because of its vital role in the manufacture of steel. Over 90% of the world's consumption of this metal enters into steel manufacture, for which it can be regarded as indispensable. About 30 lb. of high-grade manganese ore are consumed for every ton of steel produced, and no adequate substitute has yet been discovered. Normally, the world's resources are ample for all requirements, but in a world war, such as is in progress, steps must be taken to conserve supplies. In Germany, for instance, which before the war was the second largest consumer of manganese, ore deposits amount to very little, and by far the greater proportion of her requirements must be imported. It is not surprising, therefore, that steps are taken to economise in the use of this mineral.

Manganese is important in the production of steel, not only as an alloying element, but as a deoxidant. This latter effect, however, is often misinterpreted, with the result that the consumption is frequently excessive, which not only causes unnecessary loss, but is prejudicial to the economical result of the open-hearth process. The original ore contains manganese, and subsequent additions in the form of ferro-manganese are made in steel-making, and work by Bardenheuer and Henke* had for its object the finding of methods of operating the open-hearth furnace in the duplex process which would effect as low losses of manganese as possible in the slag.

Experiments were carried out in the melting shop on the usual furnaces working under normal conditions, and the melting records give all details about the quantities and analyses of the charge as well as of the output of steel and of slag; thus, the expert can obtain a vivid picture of the whole procedure. The experiments were carried out in the Seimen's melting shop of the Hoesch A-G. in Dortmund, which comprised one tilting and three fixed furnaces, each of 100 tons capacity, and a hearth area of 590 sq. ft. They were heated by cold coke-oven gas of about 16,500 B.th. The air was heated to between 1,050° and 1,150° C. in four checker chambers.

* Peter Bardenheuer and Georg Henke. Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung, Düsseldorf, vol. xxi, No. 16.

The furnaces were charged for the duplex process with approximately 42% scrap, 19% pig iron, and 39% molten steel from the 45-ton converters of the basic Bessemer steel works. The charging time was about 1½ to 2 hours, because of the bulkiness of the scrap. The converter metal as well as the pig iron were brought to the open-hearth furnaces in ladles by rail. The slag was skimmed off and the metal passed into the furnace by way of sand-formed runners. The time that elapsed between the tapping of the converter and the charging of the metal into the open-hearth furnace was about 25 min. As it was impossible to reduce this time, a sufficient covering of slag was maintained in the ladle to keep the steel hot.

During the course of the experiments the question arose whether it was possible to save manganese in the converter, in order to increase the manganese in the open-hearth furnace charge. An effort was made to catch the product of the converter at the moment of the highest reduction of manganese during the blowing period. This was found to be useless because the phosphorus contents are compulsorily high and necessitate the use of increasing quantities of lime thus greatly increasing the amount of slag and therefore preventing a larger retention of manganese in the metal.

The balance of four melts included a considerable proportion of material which was regarded as a special slag former and was charged into the furnace together with the molten steel. These slag formers, especially phosphorus pentoxide and silica, necessitated a considerable consumption of lime, which again resulted in the formation of a large quantity of slag, in some cases amounting to 3 or 4 tons; thus, the manganese could not return into the bath and the content in the bath was as low as 34·4% of the total quantity of manganese. Further experiments in which the slag formers were reduced to a few pounds, were tried, and the next four melts required much smaller additions of lime with the quantity of slag reduced from 10 to 4·2 %. The measures taken to effect economies in the use of manganese are summarised in the following :—

1. By modifying the construction of the furnaces, the refining effect and the charge of molten steel could be lowered about 10 to 15%, resulting in a reduction of the amount of slag and of additions of manganese.
2. By concentrating the carbon in the bath sufficiently and by avoiding a highly basic slag, the return of the manganese from the slag was greatly assisted and raised to 50 or 60% of the total. Subsequent charges of 0·8 to 1% of manganese were sufficient to produce mild steel containing about 0·5% manganese without the addition of ferro-manganese.
3. Carbon and manganese losses with the 100-ton melts are considerable; this may result in a loss of manganese up to 27%. Great improvement, however, was obtained by adopting a new method of tapping. In this method the ladle was brought to the runner from the tap-hole in an almost horizontal position and then gradually lowered to a vertical position in the course of the filling. This reduced the free fall of the metal and also the whirling action of the metal in the ladle, which had the effect of reducing manganese losses.

Machining Shells with Carbide Tools

Metallurgical developments, improved forging practice, machine tools expressly designed for the work and the use of sintered carbide tools have greatly augmented the production rate of shell-making. It is claimed that the ratio of effectiveness of tungsten in carbide tools is considerably greater than in high-speed tool steels. Some feeds and speeds are given for this type of work, and attention is especially directed to some suggestions for obtaining the maximum efficiency from carbide tools.

ONE of the main problems confronting war-time industry is maximum shell production with available facilities, such as machine tools, operating personnel, and time. The answer to this problem is, in large measure, the productivity of sintered carbide-tipped tools. The ratio of effectiveness of tungsten in carbide-tipped tools against tungsten in high-speed steel tools is very considerable, and, according to Judkins,* conservative figures indicate a ratio of a hundred to one. In a recent contribution, Judkins compared the present and previous emergency conditions in shell-making, and suggested means for obtaining increased production results.

Shells produced in the last great war, although made in large quantities, were necessarily made at slow rates of production and high costs. Cutting speeds with high-speed steel tools used 26 years ago were rarely in excess of 45 ft.-min. Coarse feeds of from $\frac{1}{10}$ in. to $\frac{1}{8}$ in. per revolution were necessary in order to secure the required rates. The machines used were largely engine lathes or single-purpose machines. Machine tools expressly designed for machining shells were rebuilt from existing general purpose machines. The various machining operations necessary to complete the shells from rough forgings were performed successively rather than simultaneously. The use of more than one tool at a time in machining a shell was exceptional. Then the shell cavity was bored, and this proved to be the slowest of operations, becoming in consequence the most severe bottle-neck of the entire undertaking. Stress was laid on bursting characteristics of the shell rather than upon the metallurgy and resulting machinability of the steel used.

The shell production schemes in the present emergency differ in many important respects from the situation which obtained prior to and during the last great war. Shells are being produced to-day in an almost infinitely greater quantity and at a greatly increased rate. To-day, largely automatic machines are employed, some of which are expressly designed for shell work. The newer machines are characterised by simplicity of operation and maintenance which makes possible the use of semi-skilled and unskilled personnel after only short-time instruction. Cutting speeds and feeds practised upon modern shells extend from approximately 300 ft.-min. at 0·02 in. feed per revolution for rough turning to about 400 ft.-min. at the same feed for finish turning. There has been a corresponding improvement in metallurgy and machinability of shell steel; it is more uniform and as a consequence the cost of producing a particular shell averages less than 25% of similar quantities in the last war. Improved forging practice and increased rates of production have, of course, played a large part in this cost reduction. Instead of one, or at most two, turning tools working on a shell, as in the last war, four or even six are used together to-day, and cut-off, base, and open-end facing, as well as chamfering tools are simultaneously cutting.

Speeds and feeds for machining shell forgings are given by using the 5 in. naval anti-aircraft shell forging as an example. The first machining operation consists in rough turning for concentricity; this is carried out with carbide-tipped tools at a speed of 260 ft.-min. with a feed of 0·04 in. Finish turning of the entire shell casing is conducted at a speed of from 240 to 360 ft.-min. at a feed of 0·026 in. Tools are changed for grinding after each 80 shells. The twenty-second operation on the shell is the machining of the copper or gilding metal rotating band. This is turned at 650 ft.-min. with a 0·039 in. feed. It is grooved and trimmed at 300 ft.-min. with a 0·025 in. feed. There has been some criticism of the practice involving a finished forged cavity, instead of the internal boring operation. Tests, however, have shown that finished-forged-cavity shells have a dispersion due to projectiles frequently less than one-half of 1%.

Getting Best Results from Carbide-tipped Tools

The urgency of the present situation calls for the widespread use of sintered-carbide-tipped tools. They are the only real answer to the insistent demands for immediate production of the immense quantity of shell required. The objective is therefore to realise the maximum usefulness from these tools. It has been the common lot of many who are now for the first time machining shell with carbide tools to experience extensive breakage in the early stages. In every case following a period of intensive observation and improvement in technique of handling and application, this breakage has virtually disappeared. This means that careful planning and careful checking preceding manufacture can obviate in large measure all but negligible tool breakage. To-day, it is taken for granted that machine tools are designed to use sintered-carbide-tipped tools, but, particularly on the new single-purpose machines expressly designed for shell machining, many of the constructional features must be carefully checked. Overhang of tool-slides at or near the end of the stroke may easily lead to deflection sufficient to chip the cutting tool. Stops should be so located that they do not cause the tool block to tilt at the end of the stroke, as this likewise may involve serious tool trouble. Both the volume and method of application of the cutting fluid should be carefully observed. A flood of cutting fluid must be thrown directly upon the

* "Machining Shell with Carbide Tools." By Malcolm F. Judkins. Contributed by the Machine Shop Practice Division to the American Society of Mechanical Engineers (Oct., 1941). *Mech. Eng.*, Dec., 1941, 0, 859.

tool-point at all times that the machine is operating. Any dribble or spray of cutting fluid striking a hot tool tip will cause the hard metal tip to crack. Modifications in the fluid system, including adjustment of the valves which control the flow, should be locked so that the operator cannot shut off the fluid to indulge his own comfort in avoiding spattering. Coolant pipes should be rigidly attached to each moving tool block so that the position of the stream is fixed. If insufficient dispersion of the fluid results from the original nozzle, another flatter nozzle with more lateral coverage should be provided.

Most shell lathes are equipped with live or ball-bearing centres. The action of these should be carefully studied, as in some instances the thrust of the tools tend to lift the shell from the tailstock centre, stopping its rotation.

Shell forgings themselves should be carefully examined and inspected. If excessive variation is noted with respect to size, concentricity, hardness and scale, the shell should be carefully sorted so that each type may be run through as a unit under conditions which can be varied to suit the case. The appearance of a badly eccentric shell in the midst of a lot of concentric forgings may destroy an entire set of carbide tools. A hard shell, resulting from abnormal cooling, may also cause serious difficulty. Such irregularities must be isolated for separate treatment.

With regard to the cutting tools themselves, there exists a very real need for standardisation to avoid unnecessary delays. A wide range of accurately sized, cold-drawn shank steel sections is available, and there is practically no excuse for designing a shell tool with shank dimensions not to be found in this standard size group, except obviously special items, such as skiving and dovetail forming tools. Steel for sintered-carbide-tipped tool shanks is definitely on the scarce list, particularly steel of non-standard cross-section, which must in consequence be made in many cases from the nearest standard by costly shaping, milling, or grinding. An impartial observer can find little excuse for the multiplicity of shank sizes in use to-day on the various machine tools used for shellwork. The vital importance of large and especially deep shanks for carbide-tipped tools can hardly be exaggerated. The compressive strength of sintered carbide exceeds that of any known material. It is only necessary to support the cutting tip with as deep a shank as possible to avoid breakage, even on severe intermittent cuts. If the tool shank is large enough to prevent deflection under the cutting pressure, it is practically impossible to crush the carbide tip.

There is no "trick" grind which will give best results on all shell-turning operations, but it is important to make sure that, on subsequent resharpenings, the original tool form, including rakes, clearances, and chip-curling grooves, be scrupulously preserved. A fully dimensioned tool drawing should be located at every grinding machine, and before tools are issued for use on the shell line, they should be carefully inspected, and any departures from the drawing's specification should be corrected. Negative rake is desirable for a very rough cut, because the lip angle of the tool becomes more nearly 90° and the section resisting shear from the cutting forces is proportionately increased. If the conditions, including depth of cut, feed, and concentricity, are such that a positive rake can be used, appreciably more shells per sharpening will be obtained than with a negative rake. For this reason a positive rake is almost invariably used for finish turning.

The chip-curling groove must be properly shaped and proportioned to dispose of the chip most effectively without adversely affecting the tool life. The carbide-tool suppliers, grinding-wheel manufacturers, and grinding-machine-tool builders have all contributed much valuable published information on the subject of grinding and resharpening tipped tools, including the chip-curling groove. Careless and improper grinding can do more than any single form of abuse to reduce the productivity of carbide tools. Careful attention paid to grinding will be amply repaid both in performance and in freedom from tool breakage.

The job to be done by industry can only be achieved by real co-operation among shell forgers, machine-tool builders, tool-makers, grinding-wheel and machine manufacturers, and the users of these materials and equipment. There must be free and unselfish interchange of knowledge, ideas, and experience.

Fused Alumina Cements

To a large extent this country has been dependent upon imported cements for a number of purposes, and the difficulty of obtaining supplies has been encountered by many firms. Recently, we made reference to one of these cements, which is now being manufactured by the Thermal Syndicate, Ltd., Wallsend, Northumberland. This is a fused alumina insulating cement, which is used for insulating and securing electric heating elements. We have been advised that this cement is made in two grades of fineness—40 and 60.

Fused alumina cement C for securing and insulating base-metal electric heating elements on "Vitreosil" furnace linings.

Fused alumina cement CC for use with platinum elements operating up to 1,650° C., or, for example, the alumina tubes made by the same company.

These cements have been tested under working conditions, and reports from users are very satisfactory. These home-produced materials can be used with safety, since they compare favourably with materials formerly imported, and do not injure either the element or furnace linings.

Personal

Mr. W. C. Devereux has been released from his positiou as Controller of Repair and of American and Dominion Aircraft Supplies to resume control of High Duty Alloys, Ltd., and the other companies in his group engaged on the production of vital war materials.

When appointed by Col. Moore Brabazon seven months ago, Mr. Devereux's task was to create (*a*) an organisation capable of handling imported American aircraft; and (*b*) a similar organisation to handle the repair of aircraft engines, both British and American.

With this task completed, Mr. Devereux asked to be released to devote his energies once again to production matters. He has received letters of appreciation of his work from the Minister himself and also from other officials of the Ministry of Aircraft Production.

We are notified by the Sheepbridge Coal and Iron Co., Ltd., Sheepbridge Works, Chesterfield, that their London Office address has been changed from Bush House to Aldwych House, London, W.C. 2.

WANTED immediately, Works' Manager for factory producing secondary aluminium; 150 employees. Thorough knowledge of aluminium alloys essential. Plant new and thoroughly up to date. Apply Box No. 110, *Metallurgia*.

THE Proprietors of the English Patent No. 513604, for "Improvements in or relating to alloying molybdenum with ferrous metals," and English Patent No. 513853, for "Improvements in or relating to alloying tungsten with ferrous metals," are desirous of entering into arrangements, by way of licence and otherwise, on reasonable terms for the purpose of exploiting the same and ensuring their full development and practical working in this country. All communications should be addressed in the first instance to Haseltine, Lake and Co., 28, Southampton Buildings, Chancery Lane, London, W.C. 2.

Reviews of Current Literature

"Knotted String"

Autobiography of a Steel-maker

IT is primarily the human interest in this autobiography of Harry Brierley that makes it entrancing; though the author regards writing as a hard job, there is no lack of smoothness in his literary efforts that one would expect from anyone who loathed putting his views into print. His picture of the household, the school, the playground, and the factory streets in which his early days were spent, is admirably presented, and though he can now view those early days in a more detached way, there can be no doubt he has felt the bitterness that the awakened minds of those who live in slums feel.

For some months he worked as a cellar lad in a crucible melting furnace, but he started as a cellar lad with all the advantages of knowing his way about, and knowing the men in the furnace team, because he had frequently been there as a dinner-taker, and remained, mostly in the cellars, for half a day at a time; his three older brothers also were engaged in melting furnaces. These few months is the only continuous brawn-and-sweat work he did as a steel-melter. Because his face was cleaner than another's, he was chosen by one, James Taylor, to be bottle-washer in a chemical laboratory. This meeting and subsequent association with James Taylor, who was the chemist and the sole occupant of the laboratory, proved outstanding in the life of the author. He was 12 years of age when he obtained this job, and was therefore impressionable; under James Taylor's influence and guidance he began to study, and it is evident that the influence of this man, who later became the author's friend, had a great effect upon his life from that time. He writes about James Taylor out of a grateful heart. He says of him: "It is easy now to convince me that he was not a great chemist, geologist, mathematician and scholar, but I cannot be persuaded that he was not a great man, and a great teacher of all those things which strike home by example rather than precept. Analyse him how I will into textbook scientist, routine pedagogue, halting linguist, literary and artistic mugwump, and clipper of life to formal patterns, there remains a residue of heroic striving to do a man's work in the world, supported by a frail physique and a heart of gold."

When he was 20 years of age, the author was still occupied as a bottle-washer in the laboratory, but a vacancy occurred for a laboratory assistant. At that time a premium of £50 was required to become an assistant in a works' laboratory. This problem was overcome by an arrangement to pay the premium by instalments, with money lent by a pal; thus he filled the vacancy and improved his status. Paying back the borrowed money was made harder by the death of his mother, the break-up of the home, and living in lodgings on a weekly wage of twenty shillings per week; but after a year or two, with small wage increases and exercises in cheap living, the borrowed money was repaid, and he had fallen in love with analytical chemistry and a girl; meanwhile, James Taylor was tussling with metallurgical problems in Australia.

By the time the author was 30 he had earned a small local reputation as a solver of analytical problems, and a deviser of simplified methods of analysing steel. This led to him accepting employment with another firm, where he stayed for two years, and subsequently to an appointment in Riga, then in Russia, which lasted four years. His experiences in Russia make particularly interesting reading and deals with many of the troubles associated with steelmaking at that time. Although originally engaged as chemist, he later accepted the post of works' manager.

Before quitting Riga, he received an attractive invitation to return to Sheffield and establish there a research laboratory, and, after a compromise about sharing equally the property value of prospective discoveries, each party affirmed the intent of making a working arrangement which imposed no chafing restrictions. This led to much disappointment, through the author's discovery of stainless steel, and none surely can read the chapter on stainless steel without feeling the bitterness created. Many who read this book will be familiar with the controversy at the time and how the attitude of the author was ultimately vindicated. Although the whole business was rather sordid, the author had courage with his convictions and fought successfully what must have appeared to many to be overwhelming odds. In any case of this kind the odds are always great for any man who finds himself at variance with powerful business interests, for everyone who succeeds a thousand or more have not the money or maybe the courage to fight; they submit and hope for the crumbs that fall.

The author strikes a happier vein again when he writes of his association with Brown-Bayley's, first as manager and later as a director, and it is interesting to read how, with the support of his brother, who remained his best friend, he was able to raise the quality of ingots to a higher plane. In 1920 he was awarded the only distinction he ever coveted —the Bessemer Medal—and it was in his acknowledgement of this honour he paid special tribute to his brother in these words: "My brother was already engaged in the furnaces when I began work; since 1882 we have not been separated. All the opportunities afforded to one have been shared by the other, and if it were possible to cut the Bessemer Medal in two, I would give my brother half of it."

This is a book which should be read by all, in the iron and steel industry particularly, by old and young alike, especially the latter, for it rings true, and displays courage and ability of no mean order. The reviewer has been thrilled in the reading of it, and if anything has been said about it that will encourage others to experience the same thrill, a service will have been done to industry generally, because the author's views have both breadth and depth of vision, and are founded on a practical experience which in its entirety can come to the very few. It is an inspiring book, and is written with vigour tempered with charm, but the latter seems to be the outstanding characteristic of the man.

By Harry Brearley. Published by Longmans, Green and Co., 43, Albert Drive, London, S.W. 19; and of 55, Fifth Avenue, New York, U.S.A.. Price 10s. 6d. net.

Economic Control of Iron and Steel Works

THE purpose of this book is to discuss the individual parts of economic control and their connections with each other. It should be understood that only the point of view of considering economic control as an inseparable whole of technical, commercial, administrative, and psychological questions can produce the favourable result, which should reasonably be expected from the necessary clerical apparatus. These problems are discussed from the point of view of the iron and steel industry, but the fundamental explanations can be considered as valid for industrial works generally.

It is undoubtedly true that there is frequently a distinct lack of co-operation among members of the staff of a large concern, with the result that managerial activities become mostly concerned with administrative problems. Conflicts occur between members of the different sides of the undertaking and the clashes take place mostly over administrative matters, where the various sections come into close contact. This difficulty can be largely overcome only when the fundamental principles of administration are well known and appreciated, at least by those occupying the higher positions in the sections concerned, and this book is intended as a contribution to that end. The author does not overlook the fact that the accountancy and costing section cannot be acquitted from its share of guilt that often so little understanding prevails between the various sections, but he is an engineer rather than an accountant, and has

therefore chosen a method of presentation that will better appeal to the technical and commercial sections. The accountancy method chosen differs from that which the British Iron and Steel Federation has chosen, and follows more the lines of the German publication, *Leitfaden für das Rechnugswesen in der Eisenschaffenden Industrie* (Guide for Industrial Accounts in Iron and Steel Works).

The whole sphere of economic control is discussed in five sections: Accountancy; works' accounts; job accounts; standards costs; and the final part is devoted to the organisation of economic control. The section on accountancy explains the principle of book-keeping by double entry in so far as is necessary for the understanding of this method. The second section gives the costing systems in the individual departments of a large iron and steel works, and discusses also material accounts and the organisation of stores and stocks as well as the forming, booking and controlling of wages. Work and time studies is discussed in this section, and attention is directed to the costing problem in connection with by-products. The intimate relations between problems of technical and commercial nature to those of administration, organisation, costing and psychology are admirably considered in this section. The development of general equations of costs is dealt with in the third section, and the author discusses problems of evaluation explaining the contents of production and sales statements. In the fourth section it is shown how discussions on the influence of the activity factor on costs, on the calculation of the selling price, and on the price policy of the undertaking lead logically to the development of standard costs, and how they should be used in budgeting and estimating. In the final section the author indicates proposals for improvement of the organisation of economical control based on his experience and logical conclusions.

From the foregoing brief summary of the contents of this book its comprehensive character will be appreciated; its careful study will stimulate a better understanding of the relationship which should exist between the various departments in an organisation, and which would result in an improvement in the general efficiency of the organisation. The subject is admirably presented, and since the author is an expert, the book could profitably form the basis of lectures on the subject at centres directly associated with the iron and steel industry. This book is recommended especially to readers interested in the series of articles by the author, which appeared in METALLURGIA, commencing in the October, 1938, issue under the title "Industrial Management and Production Control." Although the reader will not agree with every aspect of the subject as presented, a study of the book will certainly lead to a better understanding of the relative importance of the various parts of an organisation with a view to obtaining maximum economic control. It will stimulate much discussion, especially among leaders of the respective sections who are mainly concerned with the success of their particular section, but, if criticism is of a constructive character, greater efficiency should result.

By F. L. Meyenberg, M.I.Mech.E., with a Foreword by Sir William Larke, K.B.E., Director of the British Iron and Steel Federation. Published by Chapman and Hall, Ltd., Henrietta Street, Covent Garden, London, W.C. 2. Price 25s. net.

1941 Supplement to Book of A.S.T.M. Standards

To keep up to date its triennially published book of standards, the American Society for Testing Materials in the two intervening years issues supplements to each part of the book. The 1941 Supplement, published in December last, gives in their latest approved form the 370 specifications, tests, and definitions, either issued for the first time in 1941 or revised. The publication of this supplement completes the cycle of publication of the 1939 book of standards as a new book of standards will be prepared this year.

At present this book of standards is in three parts: Part I on metals; Part II on non-metallic materials—construction; and Part III non-metallic materials—general. The new supplement to Part I, with 126 standards, occupies some 619 pages, including specifications covering ferrous metals—aluminium and aluminium alloys, magnesium and magnesium alloys, copper and copper alloys castings, and lead and lead alloys; including two general testing methods. The 1939 book of this part comprises 1,344 pages, and the 1940 supplement contains 501 pages.

Part II includes 125 standards, and comprises 449 pages. It covers specifications for non-metallic materials used for constructional purposes, including specifications and tests for cement, gypsum, refractories, glass, concrete and concrete aggregates, etc. The 1939 book of this part contains 1,253 pages and the 1940 supplement 371 pages.

Part III, the largest supplement of the three, comprised 663 pages, and covers the following materials: Coal and coke, petroleum products and lubricants, electrical insulating materials, plastics, rubber products, textile materials, paper, etc. The 1939 book contains 1,201 pages, and the 1940 supplement 597 pages.

Index to Standards

The above supplements are designed so that users can refer readily to any particular standard or tentative standard they wish to find, but instead of incorporating a detailed subject index, the Society has again published its index to A.S.T.M. standards simultaneously with the supplements. This index can now be regarded almost as an indispensable part of the Book of Standards, since it provides references to the parts of the Book of Standards or Supplements where each of the 1,043 specifications and tests appears in its latest form.

The index gives titles and serial designations of the standards under appropriate subject headings, and there is also published as a separate feature a complete list of all A.S.T.M. serial designations in numerical order, with the page references to publications where they appear. Copies of this 196-page publication are supplied without charge on written request to A.S.T.M. Headquarters, 260, S. Broad Street, Philadelphia, Pa., U.S.A.

Copies of the Supplement, each of which includes table corrections ready gummed for fixing in the previous books, can be obtained from A.S.T.M. Headquarters, at the above address, at $3 for one part, $5 for two parts, and $7 for three parts. Each supplement is bound in durable cloth binding, designed to match the Book of Standards.

American Developments in Experimental Physics

THE publication by the Institute of Physics, in its *Journal of Scientific Instruments*, of a survey of recent American developments in experimental physics, is a particularly interesting one. This useful illustrated summary has been contributed by Dr. C. J. Overbeck, of the North-Western University, Illinois. Characteristics of the period surveyed are the great acceleration of research, the urgent need for more trained physicists, the tremendous advance in the industrial applications of recent fundamental research, and the rapid extension of experimental work demanding expensive, complicated or large scientific instruments often weighing several thousand tons.

Among the many interesting developments reported, we mention as typical examples lubrication by thin metallic films, an inexpensive substitute for the cathode-ray oscillograph, suitable for certain types of work, a simple reed frequency meter, a suggestion for a new length standard, and an induction electron accelerator from which an energy of 13 million electron volts and approximately 4 roentgens per min. of X-radiations have so far been obtained.

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